Effects of Urban Development on Herpetofauna

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FINAL REPORT

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INTRODUCTION

Habitat destruction associated with urban development may be the greatest threat to Arizona's wildlife, amphibians and reptiles included. Arizona is the second fastest growing state, and Maricopa and Pima counties are among the fastest growing counties in the United States (U.S. Census Bureau 2000). Phoenix and Tucson, the state's two largest cities, are increasing by literally hundreds of people per day. This incredible growth has lead to unprecedented sprawl, consuming pristine desert at an estimated rate of approximately 25 km^2 per year in Pima County alone (Huckleberry 2002).

Although the desert is being developed at an alarming rate, very little is known about how urbanization affects wildlife. This is especially true for herpetofauna, a group that typically receives less scientific and conservation attention than mammals and birds, which are considered more charismatic by most people. When large areas are mass graded to make room for row after row of tract homes, we can expect wildlife to be negatively affected. But what about so-called "green developments" where attempts are made to retain as much of the natural character of the surrounding desert as possible? How does wildlife respond to developments with relatively large amounts of open space? At what housing density do we start to see more serious effects? Which species are better able to coexist with humans? Answering these kinds of questions is difficult, partly because we simply haven't done the research. In reality, the scientific community is partly to blame. Well-designed studies have rarely been conducted in spite of innumerable opportunities to do so. In fairness, it would have been difficult to predict the accelerated pace at which habitat destruction due to urbanization has occurred, especially over the last 3-4 decades.

Studying the effects of urban development on wildlife is very difficult. Developers have been reluctant to work with scientists, because they think the scientists will turn up an endangered species, costing them millions of dollars in environmental compliance. In turn, scientists that work with developers risk being branded as pro-development by the environmental community. In addition, managing the problem of sprawl is exceedingly complicated, because it is closely tied to economic growth, which in turn is tied to population growth, setting up a vicious cycle. Determining the effects of development on wildlife is also going to take a while, and many scientists avoid long-term research for a variety of reasons, not the least of which is the pressure to publish, the need to obtain tenure, and the responsibility of training graduate students.

Aside from these obstacles, there is an urgent need to learn more about the effects of urban development on wildlife, so the effects can be mitigated in the future. The population problem is not going away anytime soon, so the need to coexist with wildlife and wild places is of paramount importance. In his new book, *Win-Win Ecology*, Rosenzweig (2003) contends that we will never be able to set aside all the land we need to maintain Earth's biodiversity, which leads him to make a plea for decreasing the size of our footprint and learning to design our living space in such a manner as to bring as many species along as possible. In reality, the question is whether or not we will decide that the intrinsic value of wildlife (even less charismatic species such as toads and snakes) is worth more than the extrinsic value of real estate. If we don't, then we can expect the built environment to increase at the expense of suitable habitat for wildlife. If biodiversity decreases as a result of urban development, then we may sustain large-scale negative impacts to ecological systems. In fact, there is evidence that this has already happened. For example, destructive flooding in the mid-western United States has resulted from the conversion of wetlands to agricultural fields and industrial areas, which no longer have the capacity to absorb flood waters. Ironically, the economy may suffer as well, because the value of land is related to the amount of open space and other environmental amenities such as the presence of wildlife.

As with all wildlife species, one of the biggest threats to herpetofauana posed by urban development is the loss of suitable habitat. Because amphibians and reptiles can be found in every biotic community in Arizona, conversion of desert to urban areas represents a loss of habitat. Adding to the seriousness of the situation is the fact that areas that are growing the fastest (e.g., Phoenix and Tucson) are both located in the relatively species-rich Sonoran Desert. As these cities spread across the desert, they replace natural areas that are critical to the future of amphibians and reptiles in the state.

In this report, we present the results of a two-year study designed to investigate the effects of development on herpetofauna at the single species, population, and community levels. Our goal was to conduct a before-after-control-impact (BACI) study that would allow us to compare pre- and post-development data at sites scheduled for development with sites that will remain undeveloped. We worked closely with the developer and had access to detailed development plans. However, as is often the case, development plans changed, and we were generally unable to obtain post-development data.

Another factor that made it difficult for us to examine the direct effects of development was the fact that the developer would not allow us to place our plots directly on lots that were going to be developed. However, this is probably the only realistic way to conduct this type of research, because the lots will eventually be sold, and landowners are unlikely to allow researchers on their property to gather post-development data. However, we were able to place our plots in common areas throughout the development, and immediately adjacent to lots along the margin of the development.

Despite these difficulties, we have laid the groundwork for what we feel will be a model study of the effects of urban development on herpetofauna, and this report outlines our efforts. Stone Canyon is typical of upscale developments in the region in that it consists of relatively low housing densities, large and expensive homes, and is associated with a desert style golf course all within a gated community. Residents are typically wealthy retirees who make their second homes in the desert during the winter months. Therefore, Stone Canyon is probably fairly representative of what many people may consider to be a relatively "low-impact" development. Stone Canyon is also being built at the urban fringe, and is adjacent to a large protected area (Tortolita Mountain Park – Pima County). This is typical of many developments in the area in that they too are positioned between higher density developments closer to the urban core, and protected areas on public lands (e.g., Coronado National Forest and Saguaro National Park).

We are currently continuing to conduct research at the site. One project, funded by the Arizona Game and Fish Department, is focused on the effects of the golf course (at Stone Canyon and elsewhere in the Tucson Basin) on herpetofauna. In addition, we are resurveying rock outcrops that we surveyed several years ago when the site was still pristine desert as part of yet another AGFD-funded study. We are currently requesting funding from the Arizona Water Sustainability Program to expand our research at Stone Canyon to include an examination of how the enormous influx of water from the golf course and increased population may affect herpetofauna, especially toads. And we plan to seek funding from the United States Golf Association to more closely examine some of the mechanisms that may lead to changes in the herpetofauna in and around Stone Canyon. We feel that the effects of the development are likely going to occur over the long term. The fact that we began work in the early stages of the development, has enabled us to set the stage for a long-term investigation of the effects of urbanization on herpetofauna at a variety of levels.

METHODS

Study Area

The study area is located at the Stone Canyon development site in the Tortolita Mountains, within the town of Oro Valley on the northwest side of Tucson, Arizona (Figure 1). A large portion of the area is characterized by relatively flat alluvial terrain interspersed with numerous isolated rock outcrops of various sizes. The northern part of the area is comprised mainly of steep, rocky slopes consisting of large boulders and exposed bedrock. Vegetation is typical of Sonoran Desertscrub, Arizona Upland Subdivision (Turner & Brown 1982). Common plants include saguaro (*Carnegia gigantea*), triangle-leaf bursage (*Ambrosia deltoidea*), foothill palo verde (*Cercidium microphyllum*), brittlebush (*Encelia farinosa*), prickly pear and cholla (*Opuntia* spp.), barrel cactus (*Ferrocactus wislizenii*), and velvet mesquite (*Prosopis velutina*). Elevation at the study site ranges from approximately 900 – 1100 m (2,940 – 3,700 ft).

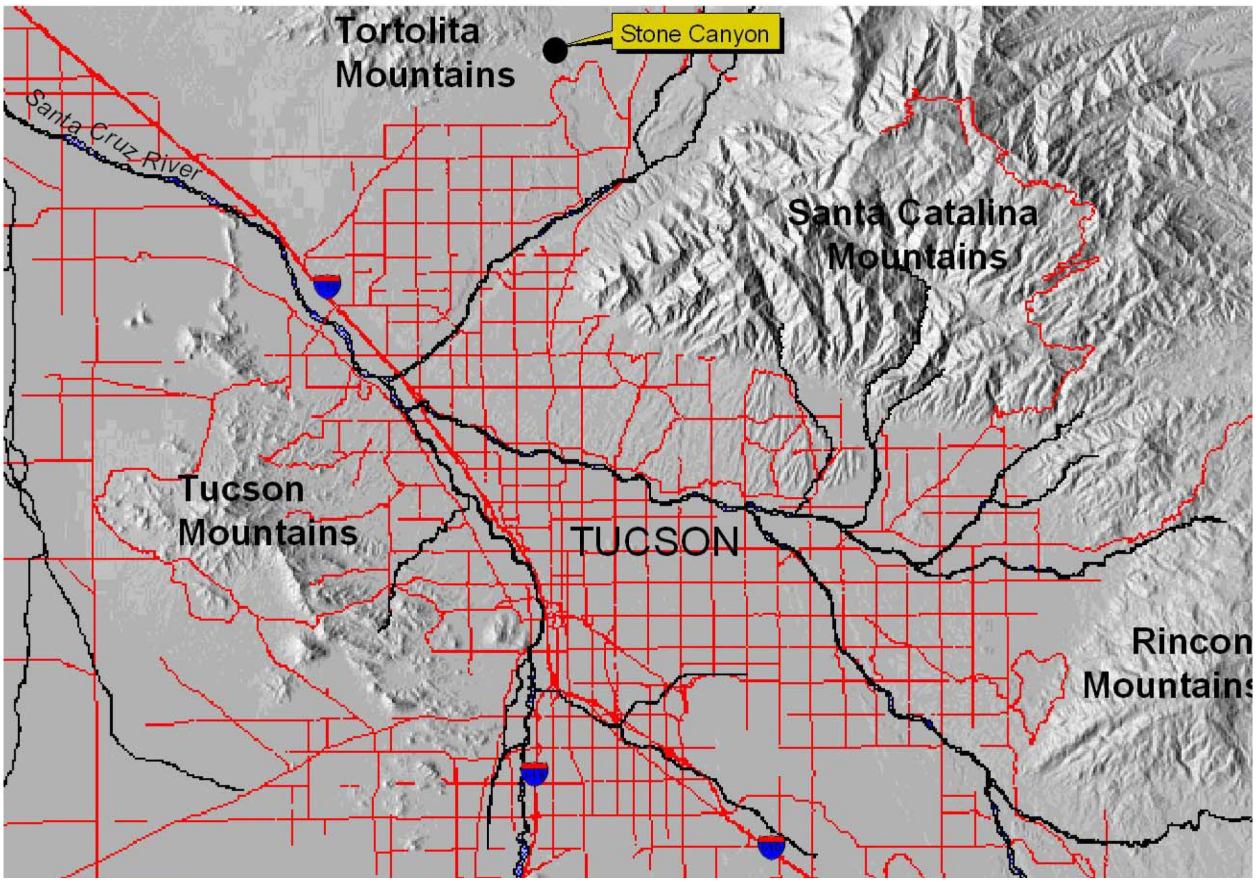


Figure 1. Map showing the location of the Stone Canyon study site north of Tucson, Arizona, near the town of Oro Valley at the base of the Tortolita Mountains.

Stone Canyon is a large, up-scale development, which when completed will consist of a resort, golf course, hiking and biking trails, and over 450 residential estates situated on one to five acre lots (Figure 2). Currently, the golf course, clubhouse, and about 45 homes are either under construction or completed. The area of the development where we are conducting most of our research is less developed with only 11 houses under construction and 14 completed (Figure 3). Only a small number of the completed homes are occupied; the others are for sale. The houses that are occupied are only

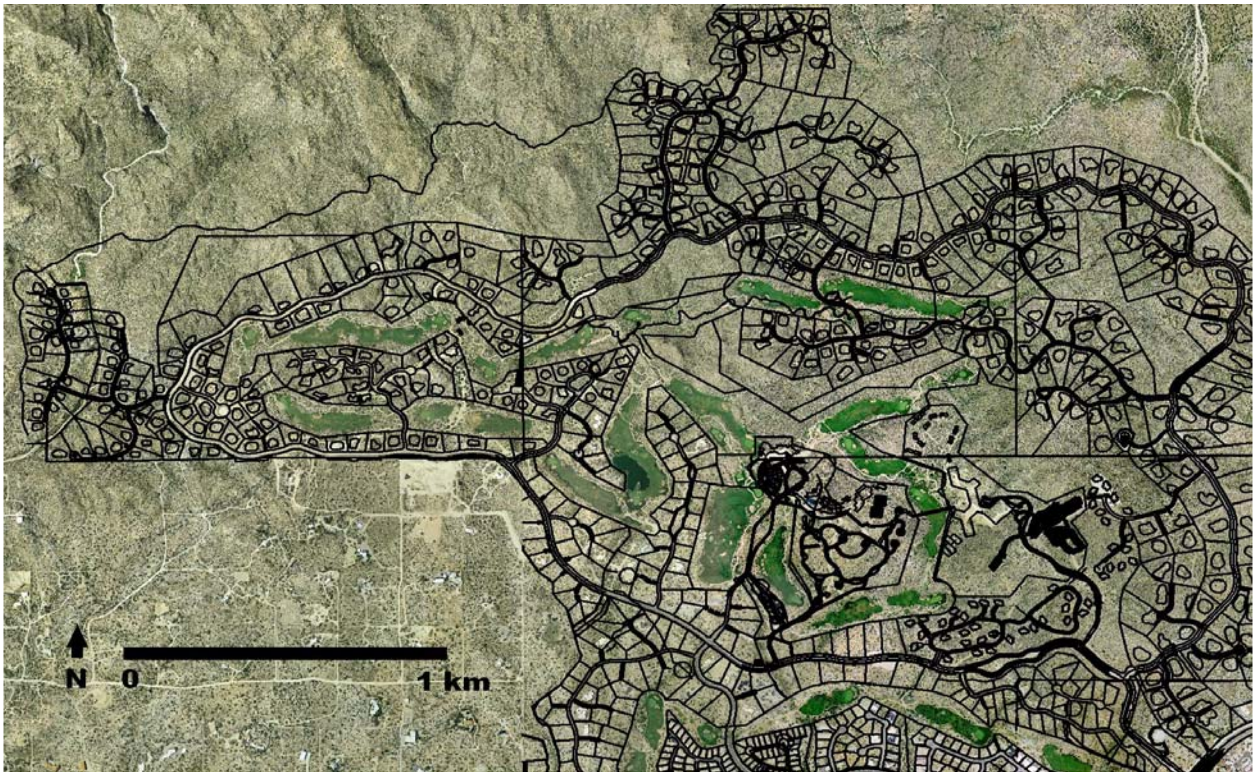


Figure 2. Aerial photograph showing the "footprint" of the Stone Canyon development near Oro Valley, Arizona.

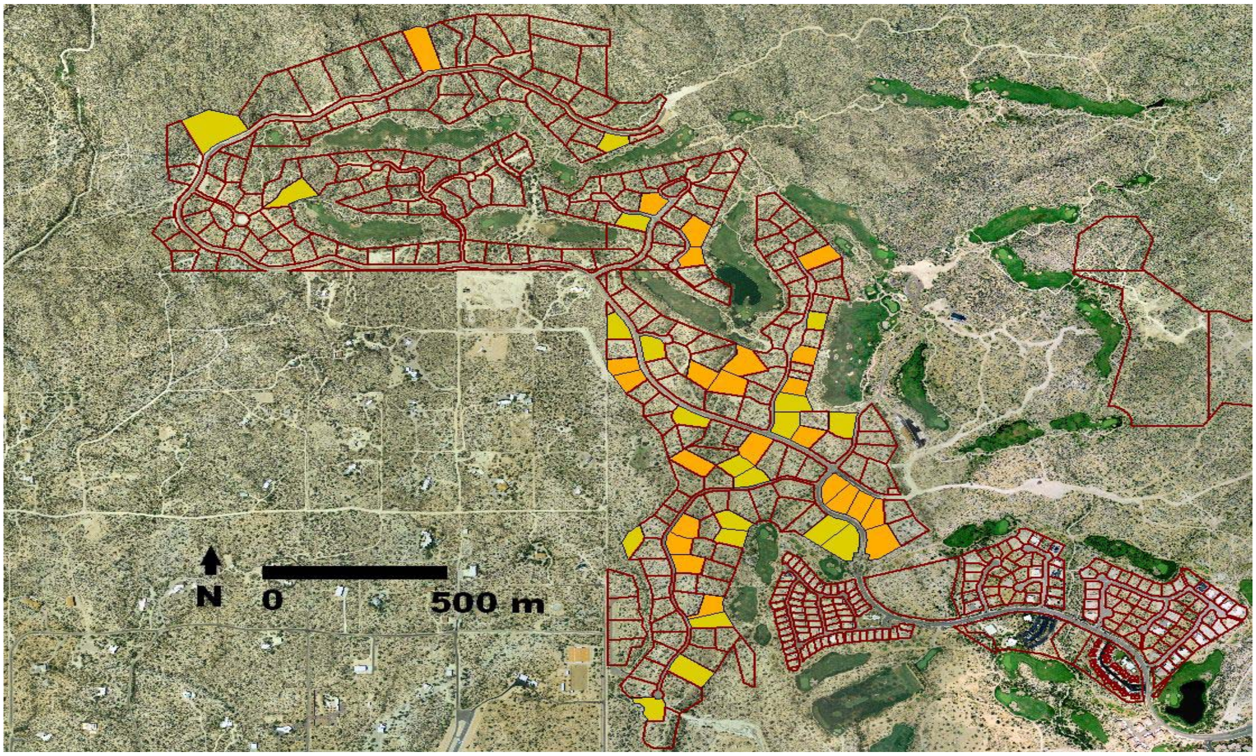


Figure 3. Orthophotoquad of the Stone Canyon development near Oro Valley, Arizona, showing lots with completed houses (orange) and houses under construction (green). Only the initial phase of the development, including the Ritz-Carlton Hotel site (far right), is depicted.

being used during the winter months, and the golf course is virtually empty during the summer, as only residents of the development are permitted on the course. Stone Canyon is an exclusive development with lots and houses that cost up to several millions dollars each. Although difficult to predict based on a variety of mostly economic factors, the developers expect the entire development to take ten years or greater.

Study Design

In general, our goal was to compare pre- and post-development data from sites that will be developed to sites that will remain in their natural condition. When it became apparent that the site where we originally planned to conduct our research (Rocking K Ranch) was not going to be developed in the timeframe needed to conduct the study, we decided to change study sites. Unlike the original site, some development had already occurred at the new site. Although not an ideal situation, we felt that changing sites was critical if we were to obtain any post-development data. As it turns out, the process of developing a site often takes many years, making it difficult to conduct a true before-after study in a two year time frame. Furthermore, developers often change their plans, particularly when it comes to the timing of construction. Although the golf course and clubhouse were already in place, we began our research at the earliest stages of the residential development. In reality, impacts to the site when we began were minor relative to what they will be when the development is completed. Therefore, we are confident that the data we gathered will provide a good baseline to which to compare.

We gathered data on a variety of single species, population, and community level parameters pertaining to the herpetofauna of the area. In this section, we describe our general methods, and specific techniques used to obtain data on each parameter we measured.

Capture, Marking, and Handling

Snakes. We captured all non-venomous snakes by hand and all venomous snakes (except coral snakes, *Micruroides euryxanthus*) with 24” snake tongs (Whitney, Inc). We transported snakes in cloth bags to our lab for processing (e.g., measuring, sexing, palpating). We permanently marked each snake by injecting a passive integrated transponder (PIT tag) under the skin. These tiny electronic devices are about the size of a grain of rice. We identified individuals by passing a PIT tag reader (Destron-Fearing Co.), which displays a 10-digit alphanumeric code, over the snake’s body. For rattlesnakes, we coded digits 0-9 with different paint colors, which were then used to paint the first three proximal rattle segments of the rattle based on a unique three digit number assigned to each snake based on the order in which snakes were captured. This gave each snake a unique rattle paint code, making it unnecessary to recapture snakes observed in the field if the paint colors were visible. In some cases, when snakes were recaptured for growth measurements or to replace their radiotelemeter, we repainted the rattle again if necessary. In general, paint marks were resilient; however, over time they will either wear off or the rattle segments containing the paint mark will break off. Therefore, painted rattles segments are not considered permanent. The paint mark also allowed us to quantify the number of times a rattlesnake shed its skin.

We anesthetized most rattlesnakes for processing in order to obtain accurate snout-vent lengths and to facilitate assessment of reproductive condition via palpation. We used plastic tubes (JB Specialties, Inc.), a hook (Rattlesnake Museum, Albuquerque, NM), and in some cases a “squeezebox” (a wooden box lined with foam padding) to safely handle rattlesnakes during capture and processing. Our experience handling venomous snakes minimized risk to both the snakes and ourselves. Snakes were released at their exact point of capture within 2-48 hours, depending on whether or not they were chosen for a radiotelemeter implant.

Lizards. We captured lizards by hand or with nooses constructed with fishing poles and fly line backing. When necessary, we transported lizards in cloth bags to our lab for processing. We permanently marked Gila monsters (*Heloderma suspectum*) by injecting a PIT tag under the skin immediately anterior to the pelvic girdle. All other species were permanently marked by toe clipping (Medica, et al. 1971; see Figure 4) and temporarily marked by painting either a number (lizards included in our mark-recapture study) or symbol on the skin that typically persists until the animal sheds. Lizards were released within 1-48 hours, depending on whether or not they were brought back to the lab for processing.

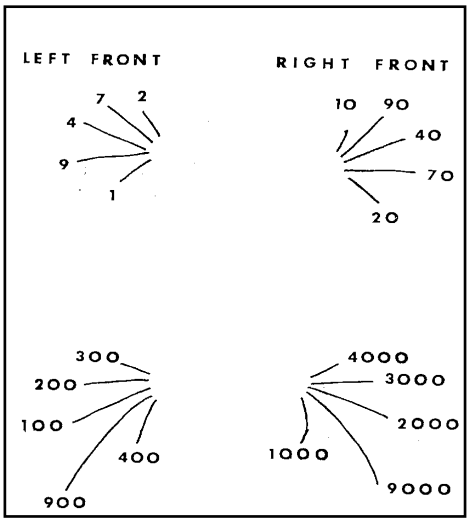


Figure 4. Diagram showing toe-clipping scheme used to individually mark lizards captured during mark-recapture sampling. It is not necessary to clip more than one toe per appendage using this method (after Medica, P. A., G. A. Hoddenback, and J. R. Lannom, Jr. 1971).

Tortoises. We captured tortoises (*Gopherus agassizii*) by hand and processed them in the field. We followed the protocol established by the Arizona Interagency Desert Tortoise Team (Averill-Murray 2000). We marked tortoises by notching with a triangular file and released them within a half-hour. We also assessed the health of tortoises, paying particular attention to the presence of symptoms associated with upper respiratory tract disease (URTD).

Toads. We did not capture any toads during the course of this study other than a few individuals of each species in order to photograph them to document their presence at the study site. However, we did conduct extensive surveys for toads and toad breeding sites, both in and away from the actual development site.

Time-Area Constrained Surveys (TACS)

We conducted time-area constrained searches (TACS) on 48 circular, 1-ha plots (Figure 5). We placed 16 plots within the development (Interior), 16 plots along the outer perimeter of lots (Margin), and 16 plots outside the development (Control). We randomly located "control" plots no less than 1 km from the development in an area that will become Tortolita Mountain Preserve, a county park that will protected from development for the foreseeable future. We surveyed plots three times each during the summer rainy seasons (July – September) of both 2002 and 2003. Each day we conducted TACS, three people surveyed three plots each as predetermined by our random sampling schedule. We searched each plot for one hour using a variety of search techniques, including actively looking for animals while walking slowly, scanning with binoculars, using mirrors to shine sunlight into crevices in search of hiding reptiles, and listening for reptiles moving in vegetation. We recorded UTM coordinates for each individual encountered. We also recorded a variety of environmental data before and after each survey, and we did not conduct surveys on days with anomalous weather conditions, such as overcast skies. Although we did not conduct trials in an attempt to detect observer biases, we did provide extensive training in survey methodology to all personnel.

Mark-Recapture

We randomly selected a subset of 6 TACS plots, two from each plot category (i.e., interior, margin, and control), on which to conduct mark-recapture efforts. In 2002 and 2003, during the months of July, August, and September, we conducted mark-recapture on each plot for five consecutive days. We captured all tree lizards (*Urosaurus ornatus*) and side-blotched lizards (*Uta stansburiana*), and for each individual we recorded UTMs, sex, age class, snout-vent length (SVL), and mass. We toe clipped and painted a number on each lizard according to our protocol (see above) and released each lizard at its exact point of capture. It usually took about 5 minutes to handle a lizard. When we resighted or recaptured marked individuals, we recorded their location, and if a month had passed, we recaptured (if they were resightings) and processed them again. We used Program MARK to estimate population size. We recorded a variety of environmental data before and after each survey, and we did not conduct surveys on days with anomalous weather conditions, which happened only once during the course of the study. As with TACS, we did not conduct trials in an attempt to detect observer biases; although, we did provide extensive training in survey methodology to all personnel in an effort to minimize variation in our data due to differences in observer abilities.

Road Cruising

We spent a significant amount of time at night driving paved and dirt roads throughout the development (Figure 6). Road cruising was very productive at the site, and nearly every animal observed on the road was alive, because the development is within a gated community with restricted access, and we were usually the only people present at night. The main road through Stone Canyon is

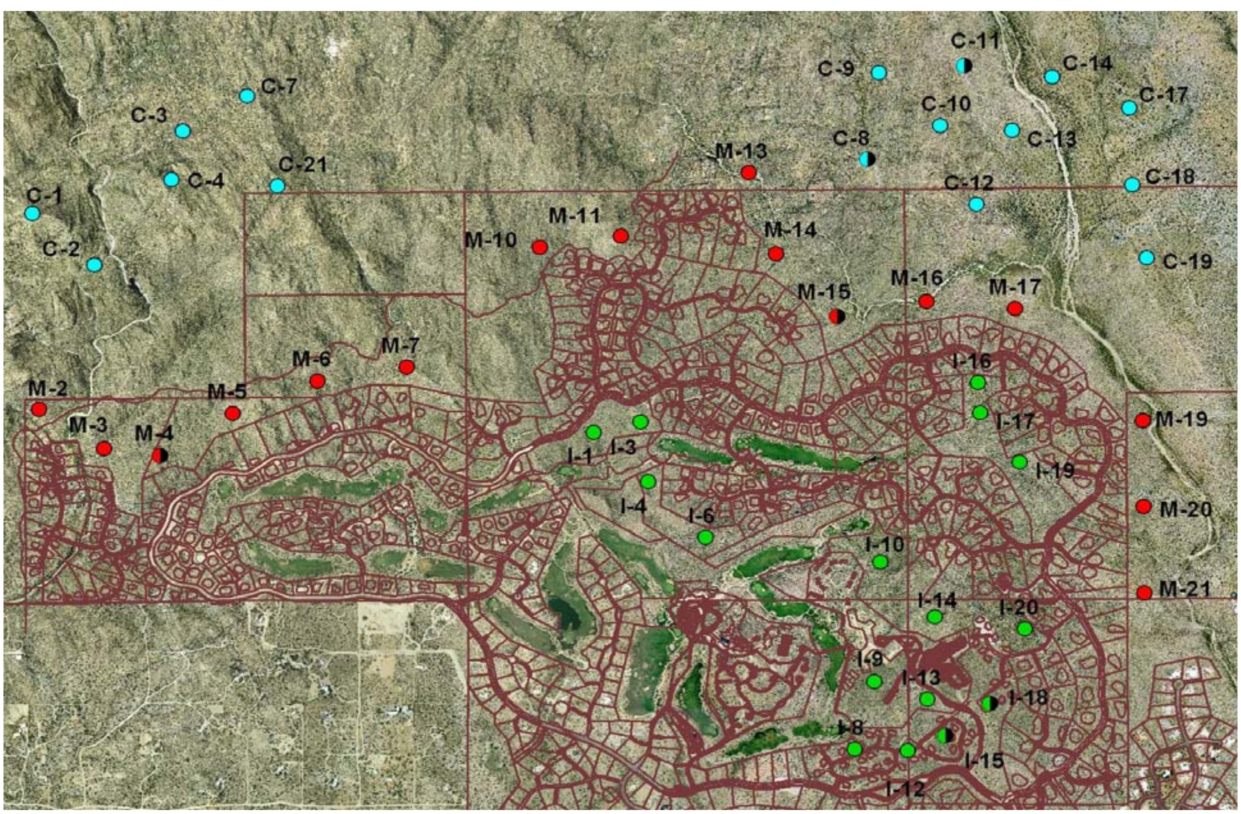


Figure 5. Aerial photograph of the Stone Canyon development site near Oro Valley, Arizona, showing 48 time-area constrained search plots (TACS) and 6 mark-recapture plots (denoted by a half-black circle).

approximately six miles in length, winding through various stages of development. The road begins at the gate house and is surrounded by several lots that contain houses, some of which are occupied and have been recently landscaped. Although we recorded amphibians and reptiles observed on the road in this area, we did not conduct intensive research (e.g., mark-recapture sampling, TACS) there. In addition to the main road, we surveyed the paved side roads leading into current and future residential areas. We also surveyed the dirt road that passes through the area that will be developed during the last phase of construction.

Golf Path Surveys

We conducted numerous golf path surveys using a golf cart supplied by the Stone Canyon Golf Club. On the majority of nights during the summer monsoon season in 2003, at least one person cruised the golf cart path that winds through the golf course (Figure 6), traversing a variety of terrain throughout the development site. We were successful at finding a variety of amphibian and reptile species during golf path surveys. We found that cruising golf paths was an excellent way to see smaller animals that may be missed during road cruising surveys using an automobile. We cruised the entire 18-hole cart path at least once per survey night, recording the locations of all amphibians and reptiles found. We also recorded other data, including distance to nearest golf course turf, temperature, and humidity. In addition, we conducted toad surveys at water features (ponds) along the golf path.

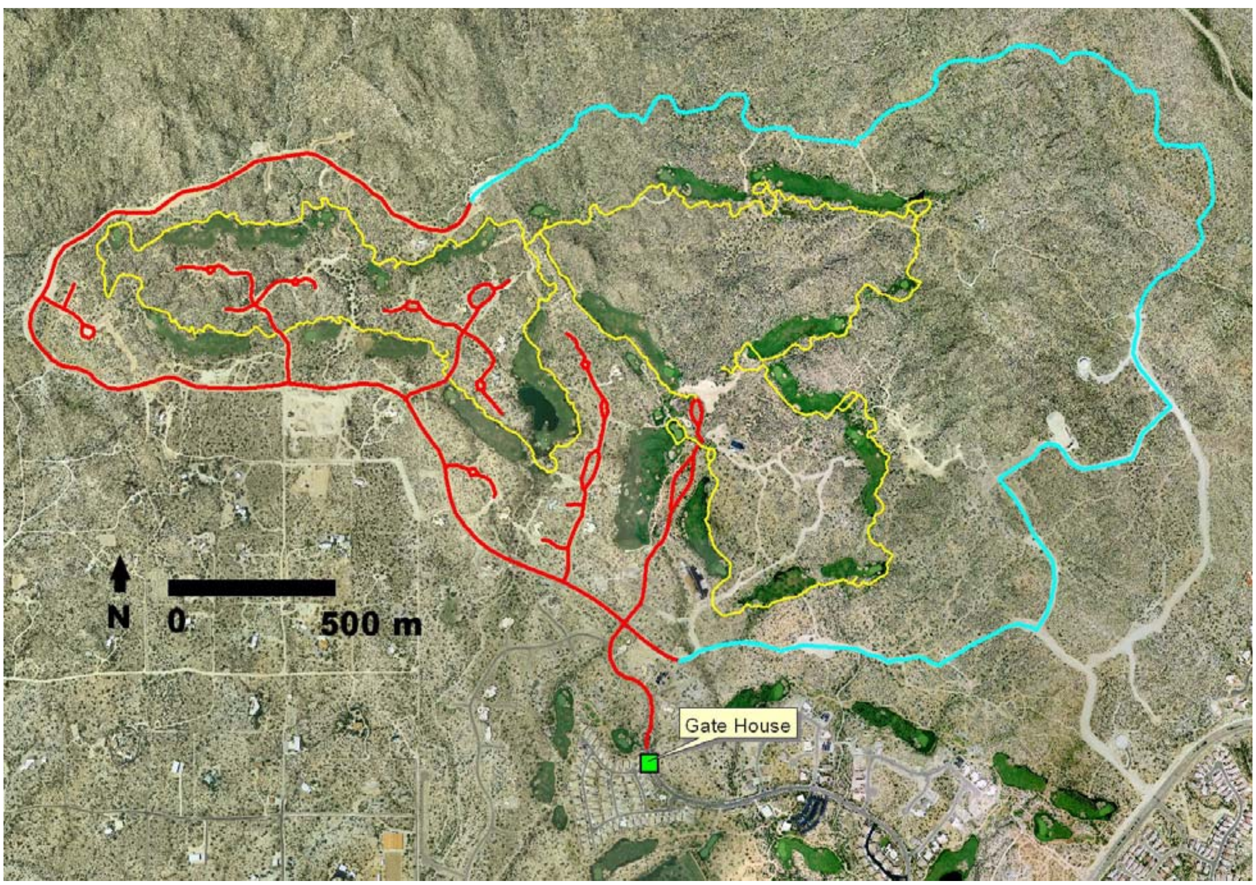


Figure 6. Aerial photograph showing roads and golf cart paths surveyed at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. Paved roads (red), dirt roads (light blue), and the golf cart path (yellow) were surveyed using automobiles and golf carts.

Incidental Amphibian and Reptile Observations

We recorded all snakes and tortoises, and all lizards of certain focal species, observed while conducting our research (e.g., during radiotelemetry sessions) and walking to and from our vehicles in 2002 and 2003. Each time an animal was observed we recorded the date, time, species, and location. We were unable to calculate the number of individuals observed per unit effort for incidental observations, because we did not keep track of time while conducting the above activities. However, incidental observations are important and may contribute to the overall species list for a given study.

Morphology of Focal Species

Snakes. We recorded SVL, tail length, and mass for all snakes captured. In addition, we recorded head width and length and rattle segment widths on tiger rattlesnakes (*Crotalus tigris)* and black-tailed rattlesnakes (*Crotalus molossus)*. We measured SVL on non-venomous species by stretching them out along a measuring tape, and we either used a squeezebox or anesthetized rattlesnakes. When using the squeezebox, we traced the total length of the snake (minus the rattle) twice on the plexiglass cover of the squeezebox. We measured the trace twice to help insure accuracy. If measurements differed by greater than 1% of the total length, then we measured again until we obtained two measurements that were within 1% of each other. We also traced the outline of the head to get length and width measurements. We tubed rattlesnakes in order to measure tail length, which we subtracted from the total length to arrive at SVL. We weighed snakes in a cloth bag and then subtracted the mass of the empty bag to determine the mass of the snake. Digital calipers were used for head and rattle measurements while snakes were anesthetized.

Lizards. We recorded SVL, tail length, and mass for all lizards captured. In addition, we recorded head width and length for collared lizards *(Crotaphytus collaris)*, regal horned lizards (*Phrynosoma solare)*, and Gila monsters. We measured SVL and tail length using a measuring tape or ruler, and we weighed lizards by the same method as snakes.

Tortoises. For tortoises, the only morphological data we recorded was midline carapace length (MCL) using pottery calipers and a measuring tape.

Toads. We did not capture, and therefore process, any toads during the course of the study.

Demography of Focal Species

Our demography data are confined to focal species (generally those species for which we obtained relatively large sample sizes), not all species observed. We sexed all animals captured (if possible) and classified each into one of three age classes: adult, juvenile, or neonate/hatchling. For a female to be classified as an adult, it had to exceed the minimum size at which gravid individuals have been found for the species (Gila monsters, Goldberg & Lowe 1997; tortoises, Averill-Murray 2002; black-tailed rattlesnakes, Goldberg 1999a; tiger rattlesnakes, Goldberg 1999b; western diamond-backed rattlesnakes [*Crotalus atrox*], Rosen & Goldberg 2002, Jacob, et al. 1987; regal horned lizards, Howard 1974; collared lizards, Ballinger & Hipp 1985, Parker 1973). For a male to be classified as an adult, it had to exceed the minimum size at which males have been found to be reproductively mature (see above citations). We distinguished neonates from juveniles based on their small size and at what time of the year they were observed. For snakes and tortoises, we designated all animals born this year as neonates; for lizards, some individuals that hatched earlier in the year approached adult size, so we based age class specification on body size. Rattlesnakes were categorized by the presence of a rattle consisting of only one segment (the button), indicating that the snake had shed only once, approximately one week after birth, and was therefore a neonate.

Radiotelemetry

We surgically implanted temperature-sensing radiotelemeters (Holohil, Ltd., Model SR2) into 33 tiger rattlesnakes. Due to premature battery failure, we were unable to track several snakes as long as intended. A total of six tiger rattlesnakes with radiotelemeters died during the course of the study: two were killed by construction workers, two were presumably killed by predators, one did not recover from anesthesia following implant surgery, and one died in transported from the field to our lab for transmitter replacement surgery (cause of death unknown). Despite these problems, we were still able to follow several individuals for two field seasons, and we were able to obtain a large dataset on numerous other individuals.

We only implanted snakes if the mass of the radiotelemeter (1.8 g, 5.2 g, or 9 g) was 5% or less of the snake's mass. This resulted in a minimum mass of 36 g to be eligible for an implant, although a snake also had to be large enough in diameter (determined by visual inspection and based on experience) to receive an implant. We anesthetized snakes using Isoflurane (Abbott Laboratories), an inhalant, which is highly soluble in tissue and allows for precise and easily controllable dosing. Using a sterile procedure (modified from Reinert & Cundall 1982), we implanted transmitters into the peritoneum (i.e., gut cavity), with the antennae placed under the skin and stretched toward the head to increase the range of signal detection. Several snakes received multiple implants. No snakes died or showed any obvious ill effects of implantation.

Spatial Ecology of Tiger Rattlesnakes

We used a Garmin E-Map, Gecko 201, or Gecko 301 (Garmin, Inc.) global positioning system (GPS) receiver to record locations. All GPS data were imported into ArcView (ESRI, Inc.) for display and spatial analyses using the Animal Movement Analysis extension (obtained online from Alaska Biological Science Center, USGS-Biological Resources Division). We used a variety of parameters to characterize tiger rattlesnake movement patterns, including total distance moved, mean distance moved per day, and whether or not the snake was moving when located. To characterize home ranges, we estimated their size using the minimum convex polygon (MCP) technique and the active kernel (AK) technique. We estimated core activity areas using the 50%, 25%, and 10% isopleths generated by the AK technique. We examined differences in movement patterns and home range size between active seasons in 2002 and 2003 when sample sizes permitted.

Potential Golf Course Effects

To investigate potential differences in tiger rattlesnakes found using the golf course with those found away from the golf course, we compared an index of condition based on body size. This index is calculated by dividing a snake's mass by its SVL, giving the mass per unit body length. A healthy snake will presumably be heavier per unit length than an unhealthy snake. We also compared movement parameters of tiger rattlesnakes found using the development area with those found away from the area (i.e., home range did not include the golf course), and with tiger rattlesnakes from undeveloped areas that we studied previously (Goode & Wall 2002).

We also examined potential golf course effects on toads. We conducted toad surveys at two man-made ponds (i.e., water hazards) along the golf course. In addition, we tallied all toads observed during golf path surveys and on several evenings when road cruising specifically for toads before and during the summer rainy season. Finally, we conducted breeding site surveys on and off the golf course on several rainy nights in July and August.

Plot Characteristics

We characterized each plot based on landscape features that we felt would reflect changes that may result from development activities. We used high-resolution (six inches per pixel), georeferenced, digital aerial orthophotoquads (available online from PAGNET, Pima County Planning Office) to calculate the area of each plot into three categories: rock outcrop, desert scrub on relatively well developed soil, and bare ground associated with anthropogenic disturbance. Using ArcView, we traced the edges of rock outcrops and other features of interest producing a polygon for which an area was calculated. We have provided an example of how we characterized plots (Figure 7). We obtained percentages of each landscape type that we plan to compare with post-development data in the future, allowing us to correlate any changes in herpetofauna with potential changes in habitat. We characterized plots in the above manner, because we felt it was a more accurate and informative than doing vegetation relevés, which we originally proposed to do. The availability of high-resolution imagery allowed us to utilize analytical techniques that are normally unavailable for exurban areas unless these areas are slated for development.

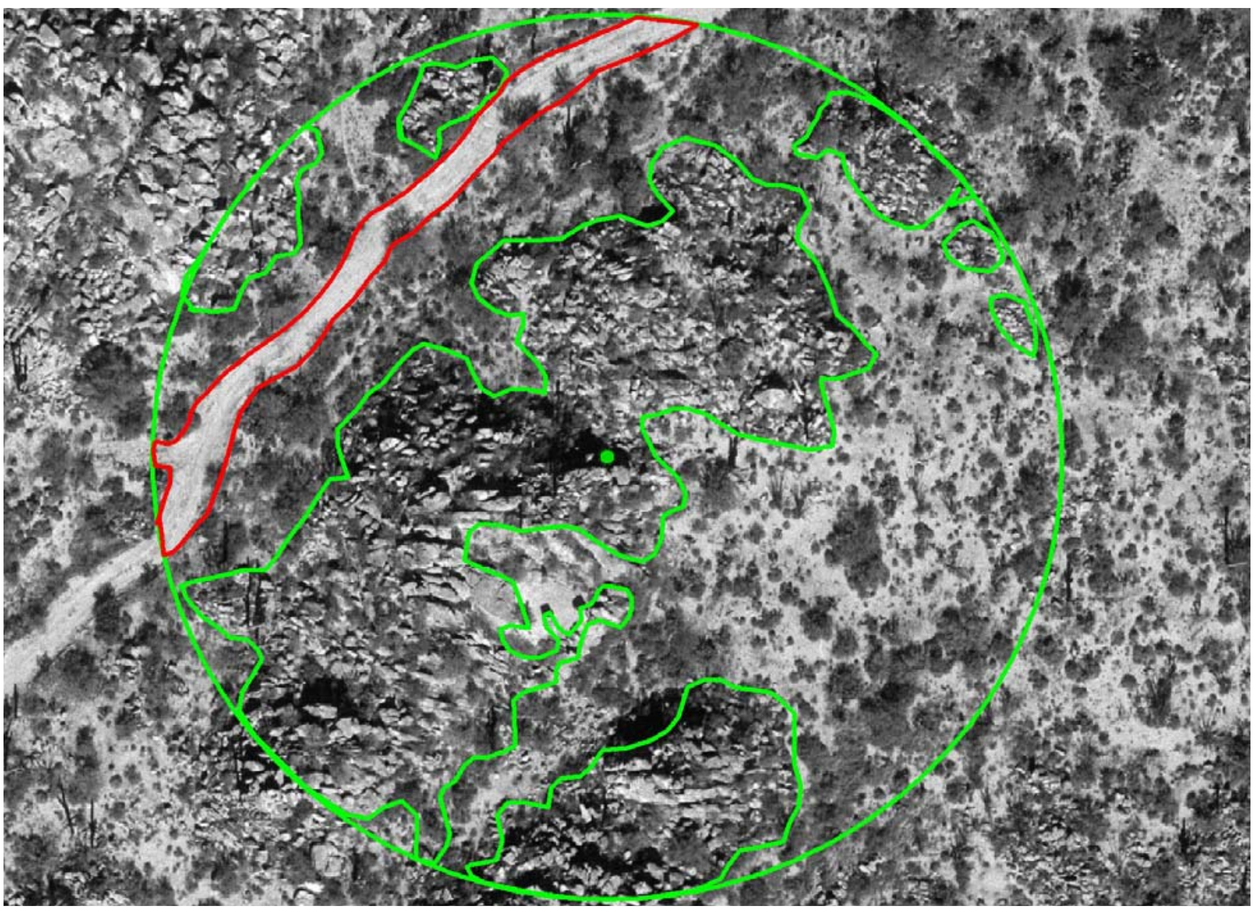


Figure 7. Close up view of interior plot I-15 at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003 depicting the manner in which high-resolution digital aerial photography was used to quantify the amount of rock outcrops (green), anthropogenic disturbance (red), and remaining flat, open desertscrub.

RESULTS AND DISCUSSION

Overall Observations and Search Effort

We observed a total of 6560 individual amphibians and reptiles belonging to 35 species (Table 1) during the study, which lasted from July – October in 2002 and May – October in 2003.

Table 1. Total number of individuals of all species observed in increasing order at the Stone Canyon study site near Oro Valley, Arizona from 2002-2003.

Common Name	Scientific Name	Number of Individuals
Ring-necked Snake	*Diadophis punctatus*	1
Western Threadsnake	*Leptotyphlops humilis*	1
Common Kingsnake	*Lampropeltis getula*	2
Long-nosed Leopard Lizard	*Gambelia wislizenii*	3
Sonoran Coralsnake	*Micruroides euryxanthus*	3
Desert Spiny Lizard	*Sceloporus magister*	5
Black-necked Gartersnake	*Thamnophis cyrtopsis*	7
Long-nosed Snake	*Rhinocheilus lecontei*	8
Nightsnake	*Hypsiglena torquata*	8
Couch's Spadefoot	*Scaphiopus couchi*	8
Western Patch-nosed Snake	*Salvadora hexalepis*	9
Banded Sandsnake	*Chilomeniscus cinctus*	9
Smith's Black-headed Snake	*Tantilla hobartsmithi*	9
Western Lyresnake	*Trimorphodon biscutatus*	12
Sonoran Spotted Whiptail Lizard	*Cnemidophorus sonorae*	24
Gophersnake	*Pituophis catenifer*	27
Gila Monster	*Heloderma suspectum*	27
Coachwhip	*Masticophis flagellum*	29
Zebra-tailed Lizard	*Callisaurus draconoides*	37
Sonoran Whipsnake	*Masticophis bilineatus*	43
Black-tailed Rattlesnake	*Crotalus molossus*	43
Eastern Collared Lizard	*Crotaphytus collaris*	47
Regal Horned Lizard	*Phrynosoma solare*	48
Great Plains Toad	*Bufo cognatus*	56
Western Diamond-backed Rattlesnake	*Crotalus atrox*	63
Tiger Rattlesnake	*Crolatus tigris*	84
Western Banded Gecko	*Coleonyx variegatus*	112
Desert Tortoise	*Gopherus agassizi*	133
Great Earless Lizard	*Cophosaurus texanus*	151
Whiptail lizard	*Cnemidophorus* spp.	183
Tiger Whiptail Lizard	*Cnemidophorus tigris*	431
Clark's Spiny Lizard	*Sceloporus clarki*	553
Red-spotted Toad	*Bufo punctatus*	624
Ornate Tree Lizard	*Urosaurus ornatus*	771
Colorado River Toad	*Bufo alvarius*	802
Common Side-blotched Lizard	*Uta stansburiana*	2290
Total		**6,629**

In an effort to make the numbers of herpetofauna observed more meaningful, we kept track of the time we spent conducting various activities, which allowed us to calculate the average number of person-hours required to observe an individual of each species group (Table 2). These figures do not include incidental observations, because it was impractical to keep track of time spent while conducting activities such as radiotracking and traveling to and from study plots. On average, we observed an individual amphibian or reptile every 0.19 hours or slightly less than every 12 minutes. Lizards were the most commonly observed species group (ca. one lizard observed every 16 minutes), followed by toads (ca. one toad observed every 42 minutes), snakes (ca. one snake observed every 5 hours and 53 minutes), and tortoises (ca. one every 34 hours). However, these numbers are misleading, because the likelihood of finding different species varies by observer activity. For example, tortoises are not found at night while road cruising, but are found relatively frequently during TACS (one tortoise observed every 8 hours and 14 minutes). Therefore, we report the average time needed to observe an individual of each species group depending on the activity in which the observer was engaged. The best method for observing toads was golf cart path surveys. The best method for observing tortoises and lizards was TACS, and the best method for observing snakes was road-cruising if effort is considered (Figure 8). These findings were not surprising to us, but we stress that they are important to consider when designing herpetological research, because individuals observed per unit effort can be used as an index of relative abundance that can be compared across treatments, taxa, or studies. Below, we break down our observations by species group.

Table 2. Total number of individuals by species group observed during different observer activities at the Stone Canyon Study site near Oro Valley, Arizona, from 2002-2003. H/I = hours required to observe one individual. Number in parentheses is total person-hours spent per method. Individuals observed incidentally are not included.

	TACS		Mark-Recapture		Road-cruising		Golf Path Surveys		Total	
Species Group	N	H/I (288)	N	H/I (565.3)	N	H/I (148.5)	N	H/I (186.6)	N	H/I (1188.3)
Snakes	23	12.52	0	0.00	84	1.77	95	1.96	202	5.88
Lizards	2512	0.11	1950	0.29	43	3.45	138	1.35	4643	0.26
Tortoises	35	8.23	0	0.00	0	0.00	0	0.00	35	33.95
Toads	18	16.00	0	0.00	134	1.11	1338	0.14	1490	0.80
Total	2588	0.11	1950	0.29	261	0.67	1571	0.10	6370	0.19

Snakes. We observed a total of 364 snakes (including incidental observations) of 17 species during the study, 241 of which we captured and processed (we processed all snakes captured). We were unable to catch numerous snakes, mainly coachwhips (*Masticophis flagellum*) and whipsnakes (*Masticophis bilineatus*), which explains why the total number of snakes observed does not match with the figure reported in Table 2.

Our large dataset pertaining to snakes is significant for several reasons. Snakes can be difficult to study, because they are inactive for large periods of time, and when active tend to be secretive, and therefore infrequently observed. Snakes are apparently relatively abundant at our study site, and because the roads are off-limits to the general public, we have an ideal situation for finding snakes. It will be interesting to look at relative abundance and community composition of the snake fauna as the development continues. We predict that road kills will increase dramatically as more and more people come to live in the development and traffic increases as a consequence. However, most people who will come to live at Stone Canyon will be winter residents, which may lead to lower road mortality, because snakes will be generally inactive when human use is at its peak.

Our snake data are also important, because snakes tend to be long-lived, especially heavy-bodied, relatively sedentary pit vipers such as rattlesnakes, for which we have the most data. Because the effects of the development are likely to be long-term, focusing on long-lived animals to investigate the effects makes sense. The problem with snakes is that recaptures tend to be uncommon; however, we are optimistic that we will eventually recapture enough individuals to provide for meaningful results, because we have marked such a large number of animals.

Lizards. We observed a total of 4813 lizards (including incidental observations) of 13 species during the study, 1008 of which we captured, and 939 of which we processed. We did not capture every lizard encountered, but we did capture all Gila monsters, horned lizards, and collared lizards, and we captured all side-blotched lizards and tree lizards on mark-recapture plots if possible (see below).

The large dataset we obtained on lizards puts us in position to make meaningful comparisons related to single species, population, and community level parameters as the development continues. In particular, the large amount of data we obtained on tree lizards and side-blotched lizards during mark-recapture efforts will enable us to compare population estimates before and after development (see Mark-Recapture section below for details). Data from TACS surveys will enable us to compare community level parameters, and data obtained from focal species (i.e., Gila monsters, collared lizards, and regal horned lizards) will also be interesting to compare to post-development data, especially relative abundance, distribution, and demography.

Tortoises. We observed a total of 184 tortoises during the study, 153 of which we captured, and 122 of which we processed in the field with minimal disturbance to the animal. We were unable to process numerous tortoises, because it was impractical to carry our processing equipment with us at all times.

The large number of tortoises at our study site is probably not a surprise given the fact that an abundance of large boulders on relatively well-developed soils is a common feature of the area. However, we think it would be a good idea to conduct more in-depth studies of tortoises in an attempt to determine any effects the development may have on them. Arizona Game and Fish Department has an active tortoise research and monitoring program; perhaps the Department could take a more active role in studying tortoises at the site where they are extremely abundant and may be subject to substantial threats as the development continues to grow. In a related study (also funded by AGFD), we are in the process of developing interpretive signs that will be placed on the golf course. One of these signs will feature the desert tortoise. We feel that a more intensive educational campaign is warranted and that people living in the area would likely refrain from capturing tortoises to keep as pets if just provided with the proper information.

Another way in which the development may negatively affect tortoises is the potential for increased prevalence of disease, in particular, URTD. Biologists have hypothesized that the incidence of URTD may increase as distance to urban areas decreases. We assessed all tortoises captured during the study for health based on AGFD protocols. We only observed 1 individual with symptoms of URTD. As the development grows, eventually reaching its maximum size of approximately 350 homes, it will be important to continue to monitor tortoise health. We have discussed our findings with AGFD scientists and Cristina Jones, University of Arizona graduate student conducting an AFGD-funded study of URTD in urban and exurban tortoises. We will be happy to collaborate with these researchers in the future if they feel that the data we are gathering are useful to them.

Toads. We observed 1490 toads (not including incidental observations), none of which we captured or processed. In reality, the number of toads observed was much higher, but we did not count every toad encountered during road cruising, because there were nights during the breeding season that there were so many toads on the road that counting them all and identifying each individual to species would have been impractical. The toads observed include all those found while conducting TACS (only 18 individuals), golf cart surveys, surveys of two artificial ponds on the golf course that act as water hazards, and surveys of breeding sites throughout the development. Only those toads found during 14 nights while specifically road cruising for toads are included in the total. These road cruising efforts were designed to be repeated in the future for purposes of pre- and post-development comparisons.

In retrospect, we feel that putting more effort into toad surveys would have been advisable. Toads are extremely abundant at the site, especially during the summer rainy season, making it relatively easy to obtain large sample sizes. In addition, toads may be a good species to monitor when examining potential effects of urban development, because they are dependent on water sources that tend to increase with human presence, and be available at times of the year when they are not normally available in natural settings. In turn, these water sources are closely tied to reproduction, the ultimate life history parameter for predicting the effects of anthropogenic disturbance. However, toads can be difficult to monitor, because populations tend to fluctuate greatly from year to year, and in some years significant reproduction may not occur depending on rainfall events.

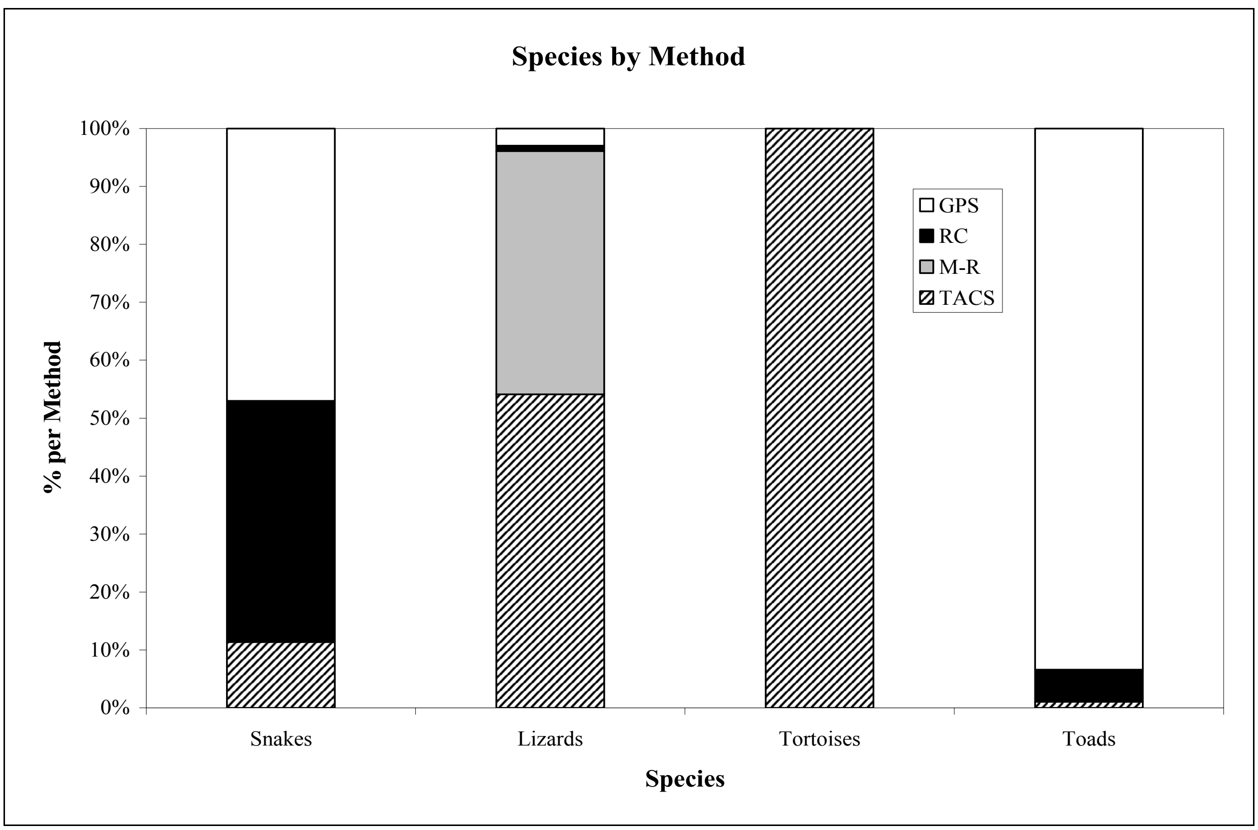


Figure 8. Percent of individuals by species group observed at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003 while conducting various research activities. GPS = golf path survey, RC = road cruising, M-R = mark-recapture, and TACS = time-area constrained search. Although more snakes were found during golf path surveys, more per unit effort were found while road cruising.

Time-Area Constrained Surveys (TACS)

We observed 2588 individuals of 21 species during TACS (Table 3). The greatest number of species observed on any plot during a one-hour survey period was 10, and the lowest number was 3.

Table 3. Numbers of individuals and individuals per hour in increasing order of all reptile and amphibian species encountered during TACS at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

Species	Number of Individuals	Hours/Individuals
Lampropeltis getula	1	288.00
Masticophis flagellum	1	288.00
Salvadora hexalepsis	1	288.00
Crotalus atrox	2	144.00
Gambelia wizlenii	2	144.00
Crotalus tigris	3	96.00
Sceloporus magister	4	72.00
Crotalus molossus	5	57.60
Phrynosoma solare	9	32.00
Masticophis bilineatus	10	28.80
Bufo punctatus	18	16.00
Cnemidophorus spp.	24	12.00
Crotaphytus collaris	24	12.00
Callisaurus draconoides	34	8.47
Gopherus agassizii	35	8.23
Cophosaurus texanus	148	1.95
Cnemidophorus sonorae	183	1.57
Urosaurus ornatus	364	0.79
Sceloporus clarki	382	0.75
Cnemidophorus tigris	431	0.67
Uta stansburiana	907	0.32
Total	**2588**	**0.17**

To facilitate post-development comparisons, we present TACS data on species richness and evenness for the three plot types (Tables 4, 5, and 6) by year and for both years combined. Overall, we observed more amphibian and reptile species and individuals on control plots than either interior or margin plots. There were only slight differences in evenness between and among plots or plot types, within or between years.

Examination of between-year data indicated that both species richness ($t = 3.54$, $df = 286$, $p < 0.0005$) and number of individuals ($t = -2.02$, $df = 286$, $p < 0.04$) were higher in 2003 compared to 2002 when pooled. However, when we examined between-year data by time of year, there were no significant differences in species richness ($t = 0.57$, $df = 94$, $p > 0.570$) or number of individuals ($t = -0.16$, $df = 94$, $p > 0.875$) in survey period one, significant differences in species richness ($t = -4.88$, $df = 94$, $p < 0.0001$) and number of individuals ($t = -3.69$, $df = 94$, $p < 0.0004$) in survey period two, and significant differences in species richness ($t = -2.13$, $df = 94$, $p < 0.036$), but not number of individuals ($t = -0.06$, $df = 94$, $p > 0.950$), in survey period three.

We also made within-year comparisons of TACS data. In 2003, ANOVA results revealed that species richness was significantly higher ($F = 15.55$; df = 2,41; $p < 0.0001$) during the first survey period (July), and number of individuals was significantly lower ($F = 8.65$; df = 2, 41; $p < 0.0003$) during the second survey period (August). In 2003, There were no differences in species richness ($F = 0.02$; df = 2, 141; $p > 0.977$) or number of individuals ($F = 0.03$; df = 2, 141; $p > 0.970$) among the three sampling periods.

One-way ANOVA revealed no differences in species richness between plot types when data were pooled across years ($F = 1.10$; df = 2, 285; $p > 0.333$), but there were significantly more individuals on control plots than on interior or margin plots ($F = 6.39$; df = 2, 285; $p < 0.002$). Within-year results revealed that there were no differences in species richness ($F = 1.63$; df = 2, 45; $p > 0.207$) or number of individuals ($F = 1.60$; df = 2, 45; $p > 0.213$) among plot types in 2002. In 2003, there were significantly more individuals on control plots than either interior or margin plots ($F = 3.12$; df = 2, 45; $p < 0.05$), but species richness did not differ ($F = 0.37$; df = 2, 45; $p > 0.690$).

Table 4. Species richness (SR), number of individuals (N), and evenness (E) for all herpetofauna encountered during time-area constrained searches (TACS) on interior plots at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. SE = standard error.

Interior	**2002**			**2003**			**Total**	
Plot #	**SR**	**N**	**E**	**SR**	**N**	**E**	**SR**	**N**
1	3	16	0.79	8	27	0.79	9	43
3	8	20	0.88	5	18	0.76	8	38
4	5	29	0.81	6	22	0.75	7	51
6	3	19	0.95	7	19	0.67	6	38
8	5	45	0.76	7	32	0.61	7	77
9	4	14	0.94	7	6	0.82	6	20
10	7	36	0.69	6	22	0.83	7	58
12	7	37	0.67	5	19	0.64	7	56
13	8	32	0.57	6	23	0.73	9	55
14	4	21	0.85	6	11	0.68	6	32
15	6	18	0.80	6	34	0.64	7	52
16	5	16	0.77	6	33	0.74	6	49
17	5	27	0.81	6	23	0.89	6	50
18	4	20	0.67	5	38	0.70	7	58
19	5	13	0.70	8	41	0.84	8	54
20	6	21	0.79	7	22	0.83	7	43
Mean ± SE	**5.3 ± 0.4**	**24.0 ± 2.3**	**0.78 ± 0.03**	**6.3 ± 0.2**	**24.4 ± 2.4**	**0.70 ± 0.03**	**7.1 ± 0.2**	**48.4 ± 3.2**

At present, we are limited in our interpretations of the potential effects of development on the amphibian and reptile community at the Stone Canyon study, because development did not occur as we expected, preventing us from making significant before-after comparisons. However, we have established an excellent baseline to which we can compare post-development TACS data in the future. We have also examined differences in species richness, numbers of individuals, and evenness between and within years, and among plot types. The most important point to make about diversity and relative abundance of herpetofauna at the site is that it is highly variable and can change from month to month, year to year, and across plot types. This provides us with a background to use as a meaningful context within which to place post-development results. Regarding relative abundance, this natural variation is not surprising, given what we know about the fluctuating nature of amphibian and reptile populations. However, species diversity is a much more stable parameter and may be more appropriate for examining the effects of development on herpetofauna, because some species fare well in urban settings while others do poorly. On the other hand, variation in relative abundance may make it difficult to detect trends.

Interestingly, our "control" plots were generally more diverse and contained greater numbers of reptiles (very few toads were observed during TACS) than either margin or interior plots. Because very little development activity has occurred, differences in reptile diversity and relative abundance is more likely due to differences in landscape structure among plot types. In general, control plots contained less rock outcrops and more desertscrub (see Plot Characteristics section below). The greater diversity in landscape structure on control plots probably contributed to increased diversity and relative abundance of reptiles. In any case, plots will be compared to themselves and not to each other in order to assess potential effects of development.

Table 5. Species richness (SR), number of individuals (N), and evenness (E) for all herpetofauna encountered during time-area constrained searches (TACS) on margin plots at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. SE = standard error.

Margin	2002			2003			Total	
Plot #	SR	N	E	SR	N	E	SR	N
2	6	17	0.82	5	13	0.76	6	30
3	7	23	0.80	8	31	0.68	9	54
4	5	20	0.78	8	36	0.67	7	56
5	5	14	0.71	5	18	0.87	5	32
6	6	17	0.77	8	14	0.88	7	31
7	4	11	0.76	8	15	0.94	8	26
10	4	15	0.88	4	18	0.78	4	33
11	4	10	0.92	5	18	0.74	5	28
13	6	32	0.72	7	28	0.84	7	60
14	7	42	0.83	6	58	0.78	7	100
15	9	35	0.74	8	40	0.76	8	75
16	8	39	0.64	9	32	0.83	9	71
17	5	12	0.79	7	37	0.58	7	49
19	8	32	0.73	10	45	0.66	9	77
20	6	16	0.80	5	34	0.73	6	50
21	7	15	0.89	4	9	0.92	7	24
Mean ± SE	**6.1 ± 0.4**	**21.9 ± 2.6**	**0.79 ± 0.02**	**6.7 ± 0.5**	**27.9 ± 3.4**	**0.77 ± 0.03**	**6.9 ± 0.4**	**49.8 ± 5.6**

Besides varying by plot type, lizard relative abundance, diversity, and evenness varied from year to year. It is important to understand this natural variation, because it will likely interact, or even mask, potential variation caused by development. Year-to-year variation in herpetofaunal abundance is common, especially in short-lived species such as the common diurnal lizard species that comprise the bulk of our data. The more data we obtain on natural variation, the better we will be able to make inferences about variation due to development. This can be accomplished by continuing to gather data on control plots through time. In our case, because development has only just begun, many of our margin plots are currently acting as control plots. As the development extends into the northeast part of the study site, margin plots will become interior plots. However, because our control plots are on land that will become a preserve, we can be relatively sure that they will continue to serve as control plots for decades to come. It is our sincere hope that we will continue to gather data at Stone Canyon for many years to come. It seems likely that only through a long-term study such as that which we envision, can we hope to truly understand the effects of the development on the herpetofauna residing there.

Table 6. Species richness (SR), number of individuals (N), and evenness (E) for all herpetofauna encountered during time-area constrained searches (TACS) on control plots at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. SE = standard error.

Control	2002			2003			Total	
Plot #	SR	N	E	SR	N	E	SR	N
1	5	9	0.91	5	29	0.79	6	38
2	8	17	0.61	5	17	0.60	8	34
3	6	23	0.80	6	27	0.76	7	50
4	5	17	0.78	8	16	0.86	9	33
7	6	33	0.70	6	21	0.81	7	54
8	6	40	0.70	7	42	0.73	7	82
9	6	50	0.73	7	43	0.72	7	93
10	7	56	0.77	5	44	0.73	6	100
11	8	26	0.85	6	22	0.78	8	48
12	4	21	0.82	5	47	0.49	6	68
13	7	47	0.65	8	59	0.70	8	106
14	5	19	0.68	9	80	0.50	8	99
17	4	24	0.72	8	36	0.63	8	60
18	8	27	0.63	7	49	0.64	7	76
19	8	38	0.73	7	31	0.66	9	69
21	6	16	0.90	8	18	0.89	7	34
Mean ± SE	**6.2 ± 0.3**	**28.9 ± 3.4**	**0.75 ± 0.02**	**6.7 ± 0.3**	**36.3 ± 4.4**	**0.70 ± 0.03**	**7.4 ± 0.2**	**65.3 ± 6.3**

Mark-Recapture

We observed a total of 1950 lizards during mark-recapture sampling (Table 2). Of the total lizards observed, we captured 587 and recaptured or resighted 424. We captured 173 and recaptured or resighted 132 tree lizards (76.3%), and we captured 414 and recaptured or resighted 292 side-blotched lizards (70.5%) (Table 7). Sex ratios of captured lizards of both species were heavily skewed towards males, especially for side-blotched lizards. Control plots had fewer tree lizards than both interior and margin plots, and side-blotched lizards were least abundant on margin plots. Tree lizards were most abundant on margin plots, and side-blotched lizards were most abundant on interior plots. We had slightly better success recapturing tree lizards than side-blotched lizards. The similarity in recapture success between species is misleading, because most lizards we observed but were unable to capture were hatchling and juvenile side-blotched lizards.

We attempted to estimate population sizes of tree lizards (Table 8) and side-blotched lizards (Table 9) using Program MARK. In several cases, the program was unable to produce an estimate, presumably because our recapture rates were too low. The largest population size estimate in any one five-day sampling period was 180 side-blotched lizards on control plot 8 in August of 2003, and the smallest estimate was four tree lizards, which occurred on four occasions.

Table 7. Summary of mark-recapture data for tree lizards (*Urosaurus ornatus*) and common side-blotched lizards (*Uta stansburiana*) at the Stone Canyon study site near Oro Valley, Arizona from 2002-2003.

		Urosaurus ornatus			*Uta stansburiana*		
Plot Type and Number	**Total Days Surveyed**	**Number Marked**	**Number Resights**	**Sex Ratio (F:M)**	**Number Marked**	**Number Resights**	**Sex Ratio (F:M)**
Control							
8	31	32	14	10:14	74	43	13:19
11	29	17	12	4:6	63	49	8:23
Interior							
15	30	23	27	6:14	82	48	11:22
18	30	35	34	13:13	100	88	10:34
Margin							
4	29	30	27	9:14	36	19	3:12
15	30	36	18	16:17	59	45	7:21
Total	**179**	**173**	**132**	**58:78**	**414**	**292**	**52:131**

Population size estimates varied greatly from month to month and from year to year for both species. However, a few general trends were evident. Population estimates tended to increase in size later in the summer rainy season in August and September, especially for side-blotched lizards (Figures 9 and 10). This increase may be partially explained by a substantial increase in precipitation in August in both 2002 and 2003.

Whatever the reasons for fluctuating population sizes, caution must be used when comparing pre- and post-development estimates of absolute abundance to examine potential effects of development. Comparisons are difficult primarily because confidence intervals associated with population size estimates tend to be large, making it difficult to tease out differences. However, analytical approaches have been developed that allow for comparisons of trends rather than point estimates. It seems reasonable to assume that when trends are echoed across plots, then the trends probably reflect reality. We are currently exploring a variety of methods for analyzing lizard population estimates, and we are confident that a satisfactory approach will be developed to compare post-development estimates with our baseline results. In addition, we plan to expand our analyses from a series of estimates for each sampling period, to overall yearly estimates. As with TACS data, our baseline data indicate that there is a great deal of variation in population sizes between and within years and within and among plot types. Understanding this natural variation is essential if we are to make sense of potential changes in population size related to development.

Table 8. Abundance estimates of tree lizards (*Urosaurus ornatus*) on six mark-recapture plots at the Stone Canyon study site near Oro Valley, Arizona, in 2002 and 2003. LCI = lower confidence interval, UCI = upper confidence interval.

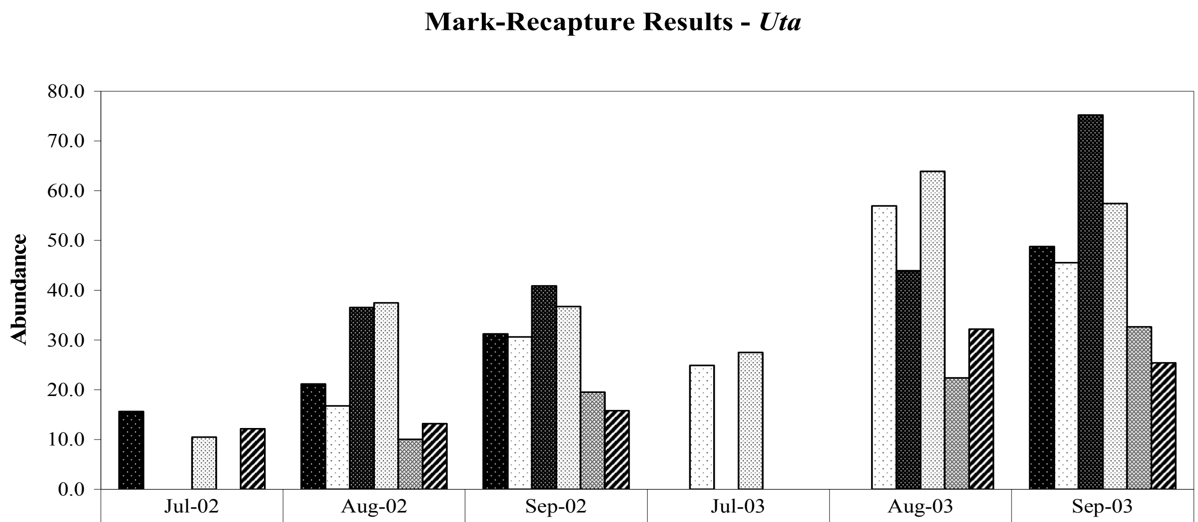
Plot	Month	Year	Abundance	LCI	UCI
Control 8	July	2002	16	9	52
	August	2002	*	*	*
	September	2002	*	*	*
	July	2003	4	4	15
	August	2003	17	12	37
	September	2003	6	4	25
Control 11	July	2002	7	4	33
	August	2002	5	3	22
	September	2002	4	2	30
	July	2003	29	10	153
	August	2003	7	5	21
	September	2003	19	6	117
Interior 15	July	2002	6	5	16
	August	2002	4	3	20
	September	2002	*	*	*
	July	2003	13	11	28
	August	2003	16	13	32
	September	2003	*	*	*
Interior 18	July	2002	15	10	40
	August	2002	*	*	*
	September	2002	15	7	60
	July	2003	17	13	33
	August	2003	15	13	26
	September	2003	32	12	135
Margin 4	July	2002	9	6	29
	August	2002	8	7	19
	September	2002	4	2	33
	July	2003	10	8	22
	August	2003	11	10	21
	September	2003	6	4	26
Margin 15	July	2002	21	16	42
	August	2002	*	*	*
	September	2002	5	2	37
	July	2003	22	13	62
	August	2003	9	7	24
	September	2003	25	11	95

*could not compute population estimate

Table 9. Abundance estimates of side-blotched lizards (*Uta stansburiana*) on mark-recapture plots at the Stone Canyon study area near Oro Valley, Arizona, in 2002 and 2003. LCI = lower confidence interval, UCI = upper confidence interval.

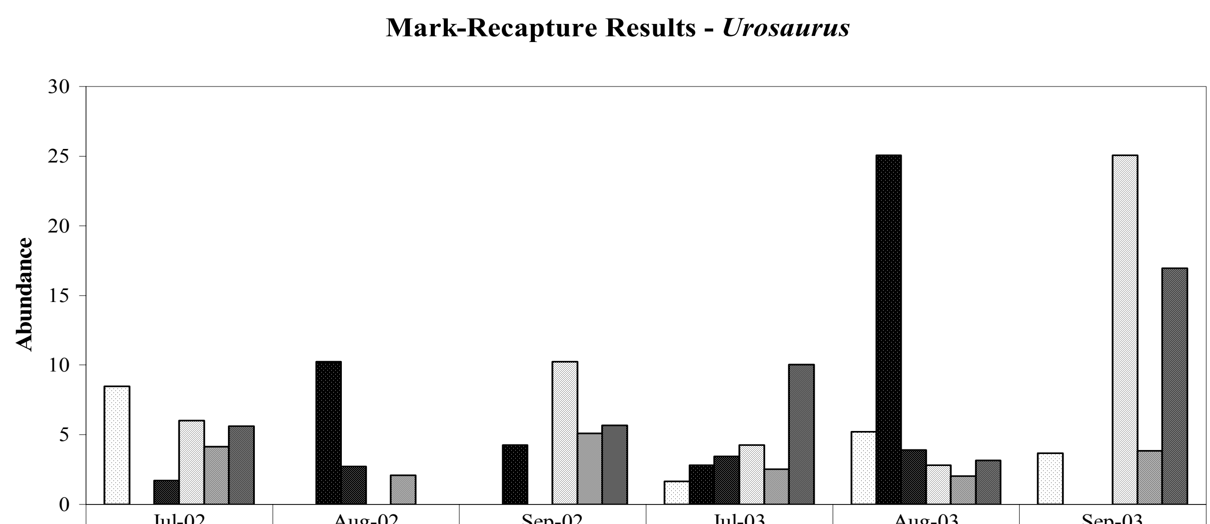
Plot	Month	Year	Abundance	LCI	UCI
Control 8	July	2002	16	12	34
	August	2002	21	17	36
	September	2002	31	20	66
	July	2003	*	*	*
	August	2003	180	45	955
	September	2003	49	36	82
Control 11	July	2002	*	*	*
	August	2002	17	13	33
	September	2002	31	22	57
	July	2003	25	10	88
	August	2003	57	41	98
	September	2003	46	30	88
Interior 15	July	2002	*	*	*
	August	2002	37	26	68
	September	2002	41	31	67
	July	2003	128	27	724
	August	2003	44	23	114
	September	2003	75	50	135
Interior 18	July	2002	10	8	25
	August	2002	37	31	57
	September	2002	37	26	68
	July	2003	28	18	58
	August	2003	64	41	124
	September	2003	57	47	81
Margin 4	July	2002	*	*	*
	August	2002	10	8	23
	September	2002	20	8	80
	July	2003	*	*	*
	August	2003	22	13	63
	September	2003	33	22	66
Margin 15	July	2002	12	9	33
	August	2002	13	11	27
	September	2002	16	14	28
	July	2003	*	*	*
	August	2003	32	25	56
	September	2003	25	19	49

*could not compute population estimate



	Jul-02	Aug-02	Sep-02	Jul-03	Aug-03	Sep-03
C-8	15.6	21.2	31.2			48.8
C-11		16.7	30.6	24.9	57.0	45.5
I-15		36.5	40.9		43.9	75.2
I-18	10.5	37.5	36.7	27.5	63.9	57.5
M-4		10.0	19.5		22.4	32.7
M-15	12.2	13.2	15.8		32.2	25.4

Figure 9. Population estimates for side-blotched lizards (*Uta stansburiana*) by month and by year at the Stone Canyon study site near Oro Valley, Arizona.



	Jul-02	Aug-02	Sep-02	Jul-03	Aug-03	Sep-03
C-8	8.47			1.65	5.2	3.67
C-11		10.25	4.25	2.8	25.05	
I-15	1.72	2.71		3.45	3.9	
I-18	6.01		10.25	4.25	2.8	25.05
M-4	4.13	2.09	5.09	2.51	2.02	3.86
M-15	5.6		5.67	10.03	3.15	16.96

Figure 10. Population estimates for tree lizards (*Urosaurus ornatus*) by month and by year at the Stone Canyon study site near Oro Valley, Arizona.

We obtained data on body size for each age class for both tree lizards (Table 10) and side-blotched lizards (Table 11). Adult tree lizards were more commonly observed than juveniles, however, the opposite was true for side-blotched lizards. Tree lizard hatchlings (n = 3) and side-blotched lizard hatchlings (n = 8) were infrequently observed. Adult female tree lizards varied in mean SVL from 45.8 mm on control plot 11 to 48.3 mm on margin plot 15. Adult male tree lizards varied in mean SVL from 48.7 mm on interior plot 11 to 50.6 mm on control plot 8. Adult female side-blotched lizards varied in mean SVL

Table 10. Body size by age class data for tree lizards (*Urosaurus ornatus*) caught during mark-recapture sampling at the Stone Canyon study site near Oro Valley, Arizona, in 2002 and 2003.

	N	SVL (mm) (mean ± se)	SVL Range	Mass (g) (mean ± se)	Mass Range
Control 8					
Hatchlings	2	26.7 ± 2.8	23.9-29.5	0.6 ± 0.2	0.5-0.8
Juveniles	4	37.3 ± 2.7	32.8-44.9	1.5 ± 0.2	0.9-2.1
Adult Females	10	47.5 ± 0.4	45.7-50.0	3.4 ± 0.1	2.8-3.8
Adult Males	13	50.6 ± 0.6	46.5-53.6	3.8 ± 0.1	3.1-4.6
Control 11					
Hatchlings	0				
Juveniles	7	37.3 ± 2.4	30.4-44.9	1.8 ± 0.4	0.9-3.3
Adult Females	4	45.8 ± 0.2	45.5-46.5	2.5 ± 0.0	2.4-2.6
Adult Males	6	50.4 ± 0.7	48.0-53.5	3.9 ± 0.2	3.2-4.7
Interior 15					
Hatchlings	1	25.0		0.6	
Juveniles	2	40.1 ± 0.9	39.2-40.9	2.5 ± 0.4	2.1-2.8
Adult Females	6	46.9 ± 0.5	45.0-48.5	3.6 ± 0.1	3.2-3.9
Adult Males	13	48.7 ± 0.5	46.0-52.0	3.5 ± 0.1	2.9-4.6
Interior 18					
Hatchlings	0				
Juveniles	9	36.8 ± 2.2	30.5-44.5	1.8 ± 0.3	0.9-3.3
Adult Females	12	47.0 ± 0.4	45.0-49.5	3.2 ± 0.2	1.8-4.2
Adult Males	13	49.7 ± 0.6	46.3-52.2	3.6 ± 0.1	2.9-4.1
Margin 4					
Hatchlings	0				
Juveniles	6	42.0 ± 2.2	31.0-44.9	2.4 ± 0.3	0.8-3.0
Adult Females	9	47.3 ± 0.5	45.0-50.0	3.5 ± 0.1	3.1-4.4
Adult Males	12	49.6 ± 0.6	45.0-53.0	3.5 ± 0.2	2.0-4.6
Margin 15					
Hatchlings	0				
Juveniles	6	34.3 ± 1.7	31.0-41.8	1.3 ± 0.2	0.8-2.0
Adult Females	16	48.3 ± 0.5	45.0-51.7	3.3 ± 0.2	1.9-4.6
Adult Males	16	50.3 ± 0.4	47.5-52.7	3.7 ± 0.1	2.7-4.4

from 45.0 mm on margin plot 4 to 47.4 mm on control plot 11. Adult male side-blotched lizards varied in mean SVL from 46.3 mm on margin plot 4 to 47.2 mm on three different plots of different types. Mean mass of both species also varied among plots. Adult female tree lizards ranged from 2.5 g on control plot 11 to 3.6 g on interior plot 15. Adult female side-blotched lizards varied in average mass from 3.0 g on interior plot 15 to 3.5 g on control plot 11. Adult male tree lizards were least massive on margin plot 4 and interior plot 14 at 3.5 g and most massive on control plot 11 at 3.9 g. Adult male side-blotched lizards varied from 3.3 g on control plot 11 to 3.7 g on control plot 8.

Table 11. Body size by age class data for side-blotched lizards (*Uta stansburiana*) caught during mark-recapture sampling at the Stone Canyon study site near Oro Valley, Arizona, in 2002 and 2003.

	N	SVL (mm) (mean ± SE)	SVL Range	Mass (g) (mean ± SE)	Mass Range
Control 8					
Hatchlings	2	28.4 ± 0.6	27.8-29.0	0.8 ± 0.2	0.6-0.9
Juveniles	34	37.0 ± 0.6	30.0-41.6	1.8 ± 0.1	1.0-2.9
Adult Females	12	46.4 ± 0.6	42.0-50.0	3.2 ± 0.2	2.3-4.1
Adult Males	19	47.2 ± 0.6	42.7-51.0	3.7 ± 0.1	2.5-4.5
Control 11					
Hatchlings	1	29.0		0.8	
Juveniles	30	37.9 ± 0.5	32.0-41.9	1.8 ± 0.1	1.2-2.5
Adult Females	8	47.4 ± 0.8	42.0.4-49	3.5 ± 0.2	2.4-4.2
Adult Males	23	46.4 ± 0.7	42.0-52.4	3.3 ± 0.1	2.4-5.2
Interior 15					
Hatchlings	2	26.5 ± 2.5	24.0-29.0	0.6 ± 0.1	0.5-0.7
Juveniles	41	36.9 ± 0.4	30.6-41.3	1.8 ± 0.1	1.1-2.4
Adult Females	10	45.1 ± 0.8	42.0-50.5	3.0 ± 0.2	2.5-4.2
Adult Males	22	47.2 ± 0.7	42.0-51.8	3.6 ± 0.1	2.5-4.6
Interior 18					
Hatchlings	2	25.3 ± 1.3	24.0-26.5	0.7 ± 0.2	0.5-0.9
Juveniles	51	37.3 ± 0.4	30.0-41.5	1.8 ± 0.1	1.0-2.7
Adult Females	9	45.8 ± 0.8	42.5-49.1	3.0 ± 0.2	2.0-3.9
Adult Males	33	46.6 ± 0.6	42.7-54.2	3.5 ± 0.1	2.4-4.8
Margin 4					
Hatchlings	1	28.0		0.9	
Juveniles	15	36.6 ± 1.0	31.0-41.9	1.8 ± 0.1	0.9-3.0
Adult Females	3	45.0 ± 1.0	43.0-46.5	3.1 ± 0.2	2.8-3.4
Adult Males	12	46.3 ± 0.9	42.5-51.5	3.5 ± 0.2	2.5-4.8
Margin 15					
Hatchlings	0				
Juveniles	30	37.1 ± 0.6	31.9-41.5	1.7 ± 0.1	1.1-2.6
Adult Females	7	46.4 ± 0.7	43.0-49.0	3.2 ± 0.2	2.4-3.8
Adult Males	21	47.2 ± 0.5	44.0-52.1	3.5 ± 0.1	2.7-4.9

It is difficult to discern any obvious patterns in body size of tree lizards and side-blotched lizards. It appears that there is considerable natural variation in these parameters, even between sites that are only separated by a short distance. The variation we observed in body size of these common lizards may prove to be important when assessing potential effects of the development. The same is true of age class differences across plots. It is obvious that highly localized effects can lead to detectable changes in lizard body size and population structure. The effects wrought by the development will occur at different scales, but it seems likely that the scale at which we have conducted mark-recapture efforts is appropriate to the scale at which the development can be expected to have an effect.

Road Cruising

We observed a total of 261 amphibians and reptiles during road cruising surveys (Table 2). We observed 134 toads of 3 species (Table 12), 43 lizards of 7 species, and 84 snakes of 11 species (Table 13). No tortoises were found while conducting road cruising surveys, although several tortoises were incidentally observed crossing roads while driving from place to place during daytime research activities. We also calculated the number of miles required to find an individual animal.

Table 12. Numbers of toads found on different road surfaces at the Stone Canyon study site near Oro Valley, Arizona, in 2003.

	Individuals Observed			Miles/Individual		
Species	**Dirt**	**Paved**	**Golf Path**	**Dirt (49.8)**	**Paved (121.4)**	**Golf Path (493.1)**
Bufo alvarius	1	35	300	49.8	3.5	1.6
Bufo punctatus	8	38	459	6.2	3.2	1.1
Bufo cognatus	0	3	41		40.5	12.0
Scaphiopus couchii	0	0	7			70.4
Total	**9**	**76**	**807**	**5.5**	**1.6**	**0.61**

Road cruising is primarily effective for finding nocturnally active toads, snakes, and lizards. When compared to other methods, road cruising was the second most effective way to find snakes (Figure 8); however, if effort is taken into consideration, road cruising is the most effective means of finding snakes. Some road cruising occurs during daylight hours just before and after sunset, when some typically diurnally active species exhibit a spike in activity (e.g., spiny lizards, *Sceloporus* spp.). However, we conducted the vast majority of road cruising surveys after dark.

Overall, we found substantially more amphibians and reptiles on paved roads than on dirt roads (animals found on golf cart paths are discussed in the next section). We found one toad every 1.6 miles of paved road driven, and one snake or lizard every 3.8 miles of paved road driven. The most common toad species, and for that matter any species, found was the red-spotted toad at one individual every 3.2 miles of paved road driven. The most common reptile species was the western diamond-backed rattlesnake at one individual found every 15.6 miles of paved road driven.

Road cruising will be an excellent technique for assessing the potential effects of development in the future, and we have established an excellent baseline to which to compare. Roads are usually the first component of a development to be constructed, because they provide access to the myriad of people (e.g., construction workers, real estate professionals, potential buyers) involved in converting natural desert to urban environment. The entire infrastructure of the development is dependent on roads. We took advantage of the presence of roads to gather baseline data that can be repeated for as long as the development exists.

Table 13. Numbers of reptiles found on different surfaces (dirt road, paved road, golf cart path) at the Stone Canyon study site near Oro Valley, Arizona, in 2002 and 2003.

	Individuals Observed			Miles/Individual		
Species	**Dirt**	**Paved**	**Golf Path**	**Dirt**	**Paved**	**Golf Path**
Callisaurus draconoides	0	2	1		205.1	633.3
Chilomeniscus cinctus	0	3	4		136.7	158.3
Coleonyx variegatus	1	17	93	186.7	24.1	6.8
Cophosaurus texanus	0	1	1		410.1	633.3
Crotalus atrox	2	26	13	93.4	15.8	48.7
Crotalus molossus	1	11	15	186.7	37.3	42.2
Crolatus tigris	4	18	34	46.7	22.8	18.6
Heloderma suspectum	6	4	17	31.1	102.5	37.3
Hypsiglena torquata	0	5	2		82.0	316.7
Lampropeltis getula	0	0	1			633.3
Leptotyphlops humilis	0	0	1			633.3
Masticophis flagellum	0	1	0		410.1	
Micruroides euryxanthus	0	2	1		205.1	633.3
Phrynosoma solare	0	7	8		58.6	79.2
Pituophis catenifer	4	4	2	46.7	102.5	316.7
Rhinocheilus lecontei	0	3	2		136.7	316.7
Salvadora hexalepis	0	1	0		410.1	
Sceloporus clarki	0	1	10		410.1	63.3
Sceloporus magister	0	0	1			633.3
Tantilla hobartsmithi	0	0	9			70.4
Thamnophis cyrtopsis	0	0	4			158.3
Trimorphodon biscutatus	1	1	10	186.7	410.1	63.3
Uta stansburiana	0	1	4		410.1	158.3
Total	**19**	**108**	**233**	**9.8**	**3.8**	**2.7**
Total Species	**7**	**18**	**21**			
Total Miles	**186.7**	**410.1**	**633.3**			

We found 7 amphibians of 3 species (all toads) and 40 reptiles of 17 species (8 lizards and 9 snakes) dead on roads during the course of the study. Not surprisingly, most of the road-killed animals we found were on paved roads (27) during the day and were generally diurnally active species (e.g., 7 regal horned lizards, 6 coachwhips, 4 patch-nosed snakes). We found 18 dead animals on the golf cart path, most of which were diurnal lizards that were likely ran over by maintenance workers who travel the cart paths with mowers, utility carts, and other equipment. We only found 2 animals dead on the dirt roads, but one was a tiger rattlesnake that was run over at night by the only vehicle we ever observed on the dirt road at night. Unfortunately, we were responsible for the deaths of 7 animals, most of which were small toads and banded geckos that can be very difficult to see at night and often run towards the vehicle, making them difficult to avoid.

Large numbers of animals are killed on roads, providing an opportunity to examine mortality related to urbanization. The relatively small number of individuals that we found during the course of this study can be easily explained by the low volume of traffic at the site. Stone Canyon is a gated community, and even though only a relatively small number of houses are currently occupied, the gatehouse has been manned almost from the time construction began. Access to the site is tightly controlled, which has had the effect of minimizing traffic. However, traffic from construction workers and people involved in managing the site, including a large golf course maintenance staff, has led to moderate traffic during daylight hours. We rarely see vehicles on the road at night other than the occasional automobile belonging to one of the few residents living in the southern part of the development.

Although traffic volume is low, we have observed people, primarily involved in construction, driving at high speeds on the roads. The road-killed animals that we have observed are primarily diurnal species, indicating that they were likely run over by construction workers.

As the development grows and more people come to live in Stone Canyon, we expect traffic volume to increase dramatically, leading to a significant increase in road mortality. Other researchers have found that the number of amphibians and reptiles killed on roads can be alarmingly high (reviewed in Trombulak and Frissell 2000). Indeed, the problem of road mortality is considered an important issue by the conservation community as evidenced by an entire issue (Volume 14, Number 1) of the journal *Conservation Biology* that was devoted to ecological effects of roads on wildlife.

Herpetofauna are perhaps more vulnerable to road mortality than other vertebrate species, because they are terrestrial, relatively slow moving, and commonly use roads to thermoregulate. One study (Rosen and Lowe 1994) estimated that approximately 175 snakes per kilometer are killed on Highway 85 where it passes through Organ Pipe Cactus National Park in the southern Arizona. At Saguaro National Park, a short distance from our study site in upland desert that is very similar to the Stone Canyon site, biologists have conservatively estimated that approximately 51,000 vertebrates die every year on park roads (N. Kline, Saguaro National Park, personal communication). Amazingly, of the 51,000 vertebrates killed on roads, 44,000 were amphibians and reptiles (mostly toads at night and lizards during the day).

Some species are particularly vulnerable to road mortality. For example, turtles and tortoises are vulnerable, because they are slow to reproduce, meaning that even the death of a few individuals can have a negative impact on a population. Snakes may be more susceptible to road kill because they tend to be stretched out on roads and are difficult to avoid by motorists. Adding to the problem with snakes is the fact that some people are known to intentionally run them over. Toads, especially explosive breeding desert species such as those found at the Stone Canyon study site, come out in huge numbers on rainy summer nights to breed. Breeding sites often include roadside ponds created by drainage ditches, resulting in large numbers of toads being killed on adjacent roads. In reality, we feel that road kill will end up being the most significant source of mortality for herpetofauna at Stone Canyon. Although, this may be mitigated by the fact that Stone Canyon is essentially a community of winter residents, and amphibians and reptiles are rarely found on roads during the cold winter months.

Golf Path Surveys

We spent 186.6 hours (Table 2) and traveled 633.3 miles while conducting golf path surveys (Table 13). Our data on toads only includes 493.1 miles, because we did not start counting toads until 2003 (Table 12). During golf path surveys we observed 807 toads, which differs from the figure of 1338 presented in Table 2, because it only includes toads found on the cart path and not during pond surveys. We observed 233 reptiles belonging to 21 species, 125 of which were lizards (93 banded geckos and 17 Gila monsters) and 98 of which were snakes (the large majority of which were rattlesnakes).

We found one toad every 0.61 miles of golf path driven and one snake or lizard every 2.7 miles of golf path driven. The most common toad species, and for that matter any species, found was the red-spotted toad at one individual every 1.1 miles of golf path driven. The most common reptile species was the banded gecko at one individual found every 6.8 miles of golf path driven. Interestingly, the most common snake found on the golf cart path was the tiger rattlesnake at one individual per 18.6 miles of golf path driven.

The number of amphibians and reptiles found dead on golf cart paths (18) was higher than we expected, especially compared to roads (29). Therefore, our results suggest that the number of amphibians and reptiles killed on roadways will be higher at Stone Canyon, or at any other development that includes golf courses than at a comparably sized development that does not have golf courses.

The opportunity to conduct golf path surveys is probably the most unique aspect of this study. The golf cart path traverses rocky terrain where it is not practical to build much larger roads. Therefore, we were able to conduct extensive surveys in areas that would have to be surveyed on foot. Also, the golf path runs through the middle of the development, rather than around the edge, so the potential for effects of the development to be detectable seem greater. Finally, because the golf cart path is adjacent to the golf course, and surrounded by heavily irrigated, landscaped vegetation, it should allow us to directly assess effects of the golf course itself on herpetofauna. In a recently funded AGFD project, we will be assessing the effects of golf courses of varying ages, including the Stone Canyon course, on amphibians and reptiles.

Unfortunately, we did not obtain permission to survey golf paths until early September of 2002. Golf path surveys immediately proved to be very successful, and we began cruising the golf paths as often as possible. In 2003, we surveyed golf paths several nights per week and observed a large number of toads, snakes and nocturnally active lizard species. In addition, we observed larger numbers of smaller snake species (e.g., banded sand snakes, *Chilomeniscus cinctus*; southwestern black-headed snakes, *Tantilla hobartsmithii*) than during road cruising, presumably because golf carts travel at a slower rate of speed, and observers are closer to the roadway, making it easier to detect small animals. We also found a much greater number of tiger rattlesnakes and lyre snakes, two of our focal species, on golf cart paths, presumably because they are both primarily saxicolous species and the golf path travels through relatively rocky areas.

Incidental Reptile and Amphibian Observations

We incidentally observed 686 reptiles (numerous toads were incidentally observed, but not recorded) during the study, which included 89 tortoises, 241 lizards, and 356 snakes during the two-year study. All reptiles observed while radiotracking tiger rattlesnakes and walking or driving to and from study plots were classified as incidental. We were unable to determine the number of incidental observations per unit effort, because we did not keep track of time while traveling to and from plots. Also, because we were not specifically searching for amphibians and reptiles during these times, we felt that comparing what we found to other methods of finding animals would not be legitimate. For example, we found a large number of tortoises during mark-recapture sampling, but our efforts were focused on finding lizards. Even so, we found 24 tortoises on plot M-4. It seems likely that we would have found considerably more tortoises if we were targeting them in our searches. Perhaps this is an indication of the high density of tortoises found on site.

Incidental observations can be important, especially when compiling a species list for an area, and when obtaining additional individuals of focal species, such as snakes for radiotelemeter implantation. However, it is difficult to quantify effort expended in finding incidentals, so comparing results to time-based survey results is probably not legitimate. One way to make incidental observations more useful is to record the observers' activity when the animal is observed. At least this way, incidental observations can be compared among survey methods. We did not always record our activity when encountering incidental amphibian and reptiles. This led to problems when compiling data for reporting purposes. We could not easily or quickly address these problems, because the number of incidental observations was high, and it would require that we go through the records one by one. Nevertheless, we incorporated our incidental observations into this report when we felt that it was important to do so.

Morphology of Focal Species

Raw data for all focal species are shown in Appendix A. We summarized processing data for tiger rattlesnakes (Table 14). Male tiger rattlesnakes were longer and more massive than females. We also summarized body size data by gender and age class where possible for 6 focal species (Table 15).

Table 14. Summarized processing data for all tiger rattlesnakes (*Crotalus tigris*) captured at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

Parameter	Females	Males
% Adult	36.1%	63.9%
SVL	598 $\pm$ 9.1	635.1 $\pm$ 8.0
Mass	190.3 $\pm$ 10.2	239.8 $\pm$ 11.4
Head Length	26.1 $\pm$ 0.4	28.0 $\pm$ 0.5
Head Width	18.9 $\pm$ 0.3	20.9 $\pm$ 0.6
Number of Segments	7.5 $\pm$ 0.4	7.9 $\pm$ 0.3
Rattle Length	32.3 $\pm$ 1.7	37.4 $\pm$ 1.2
% with Broken Rattle	64.0%	66.0%

Body size data can be important for a variety of reasons. For example, data on length and mass can be used to calculate a condition index, which is presumably related to health. Snakes that are more massive per unit body length are probably healthier, and in turn, are likely to reproduce more. By examining body size of snakes before and after development occurs, we may be able to detect important differences. Below, in the section on potential effects of the golf course, we explore this possibility further.

Table 15. Sex ratios and body size data for all individuals captured of 6 focal species at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

Species (F:M)	Sex	SVL	Mass
Crotalus atrox (26:35)	Females	853.2 ± 28.5	494.1 ± 74.2
	Males	934.6 ± 26.9	660.6 ± 70.4
Crotalus molossus (19:24)	Females	833.9 ± 19.2	367.5 ± 37.9
	Males	852.9 ± 23.8	432.5 ± 36.7
Crotaphytus collaris (23:19)	Females	86.7 ± 0.9	24.2 ± 1.2
	Males	95.5 ± 1.5	34.0 ± 1.9
Gopherus agassizii (33:61)	Females	237.3 ± 3.1	
	Males	238.9 ± 3.6	
Heloderma suspectum	All	298.4 ± 6.5	384.6 ± 18.7
Phrynosoma solare (22:24)	Females	103.1 ± 3.3	59.1 ± 3.5
	Males	87.0 ± 1.5	40.9 ± 3.1

Demography of Focal Species

We summarized age-class data for all three rattlesnake species present at the study site (Figure 11).

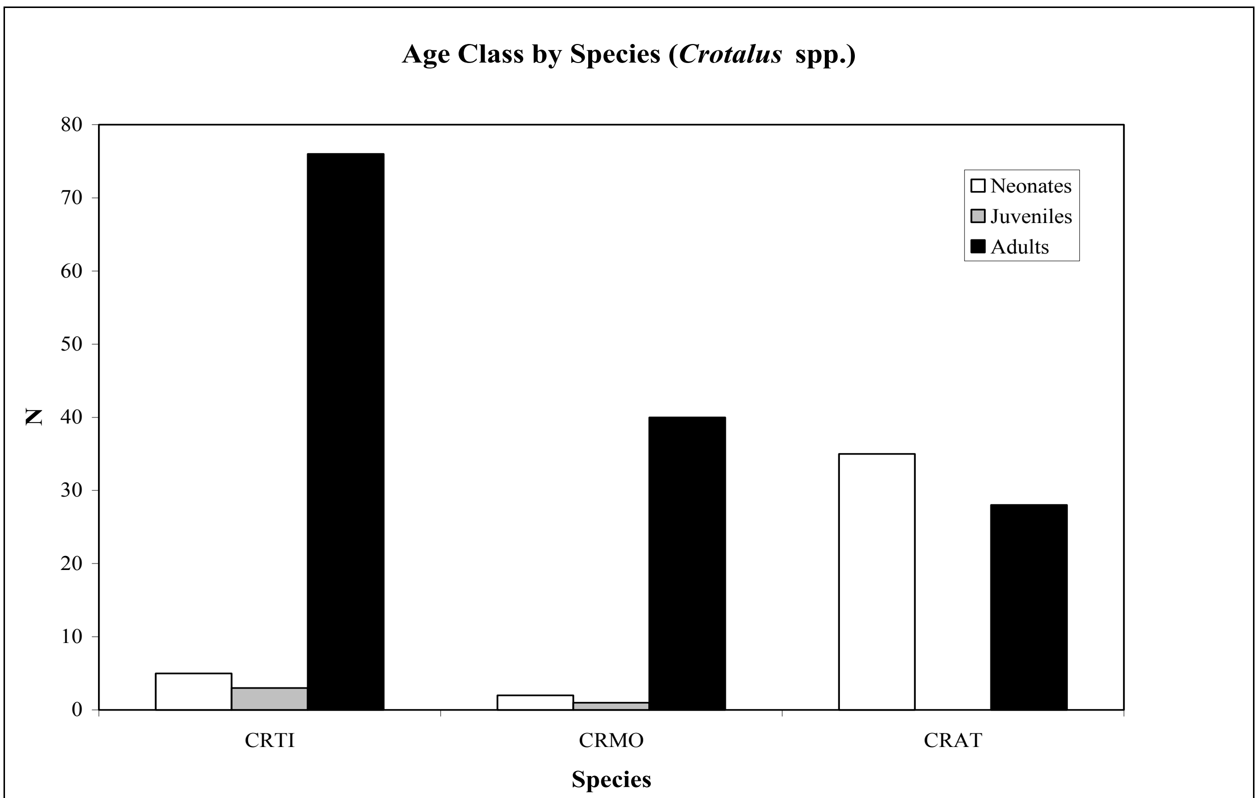


Figure 11. Age class data for all three rattlesnake species present at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. CRTI = *Crotalus tigris*, CRMO = *Crotalus molossus*, CRAT = *Crotalus atrox*.

Age class data of tiger rattlesnakes and black-tailed rattlesnakes are heavily biased towards adults, although the same cannot be said for western diamondback rattlesnakes, of which we found more neonates than adults. In general, neonate and juvenile snakes are very difficult to find, and tiger rattlesnakes and black-tailed rattlesnakes are no different. However, young-of-the-year western diamond-backed rattlesnakes are relatively common, especially in late summer and early fall. In fact, we found more neonate than adult western diamond-backed rattlesnakes during the study. To clarify, thirteen of the neonate western diamond-backed rattlesnakes we observed were from a single litter born to a gravid female that we captured near the golf course. The remaining 23 "neonates" were actually young-of-the-year that had already dispersed. We termed these snakes neonates to distinguish them from juveniles, which are snakes that are in their second year of life, but have not yet reached the minimum SVL for which the species is known to reproduce. We found nearly as many young-of-the-year western diamond-backed rattlesnakes as we did adults (n = 28).

Why young western diamond-backed rattlesnakes are common and young tiger and black-tailed rattlesnakes are so rare is an interesting question. Perhaps it is because western diamond-backed rattlesnakes have larger litter sizes on average, larger young at birth, and they grow to a much larger adult size. The reason is apparently not related to the number of adults at our site, because both tiger and black-tailed rattlesnakes were more common than western diamond-backed rattlesnakes. It will be interesting to see if the development has differential effects on rattlesnake species. One might predict that the strongest effect will be on western diamond-backed rattlesnakes, because their young are more easily found, and may be exposed to more danger than the other two species.

We also summarized age class data for three focal lizard species and tortoises (Figure 12). Age classes for all focal species were heavily biased towards adults. Monitoring age class distributions to

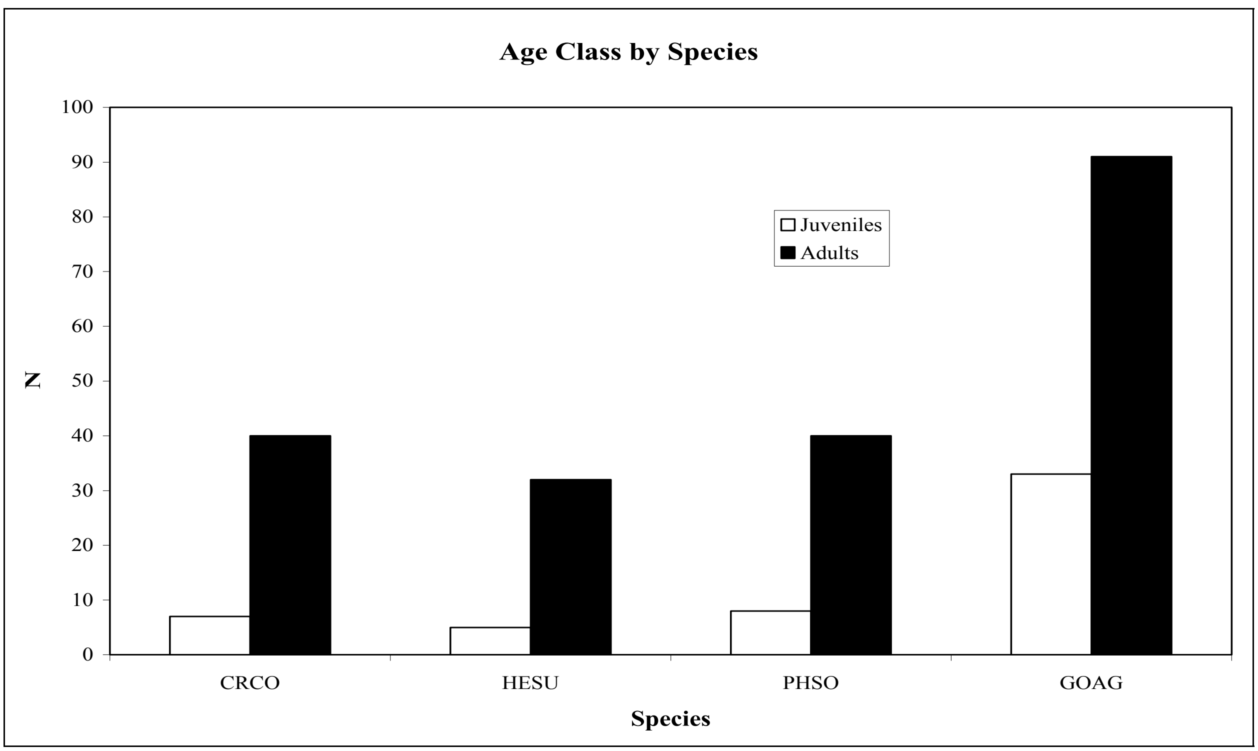


Figure 12. Age class data for three lizard species and tortoises present at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. CRCO = *Crotaphytus collaris*, HESU = *Heloderma suspectum,* PHSO = *Phrynosoma solare*, GOAG = *Gopherus agassizii*

see if they change with increasing development may prove to be useful. Theoretically, development could lead to a variety of changes in population structure, depending on the species. For example, if reproduction is affected by anthropogenic influences such as increased mortality or increased availability of resources such as water, then age class structure may change. If reproduction increases, then we may see a shift towards an overall younger population, or age at maturity could even decrease if animals are able to obtain larger body sizes relatively sooner.

We determined size class distributions for all focal species by sex, except for Gila monsters, for which we were unable to determine gender reliably. Tiger rattlesnake males and females were strongly skewed towards large adults, and the largest individuals were males (Figure 13). Black-tailed rattlesnakes were biased towards adults, but individual males and females were more widely distributed across adult size classes (Figure 14). Western diamond-backed rattlesnakes were biased towards smaller individuals (obviously echoing age class structure), and juveniles were nearly absent from our sample (Figure 15). We observed more large Gila monsters, but SVL tended to be relatively evenly distributed among size classes (Figure 16). Desert tortoises were biased towards larger individuals, although we found numerous individuals that we were unable to reliably sex, indicating that they were not yet reproductively mature (Figure 17). Regal horned lizards were biased towards intermediate sized males, but larger females, and we observed numerous individuals that were apparently subadults (Figure 18). Collared lizards were biased towards larger individuals, with males being slightly larger than females; juvenile collared lizards were absent from our sample (Figure 19).

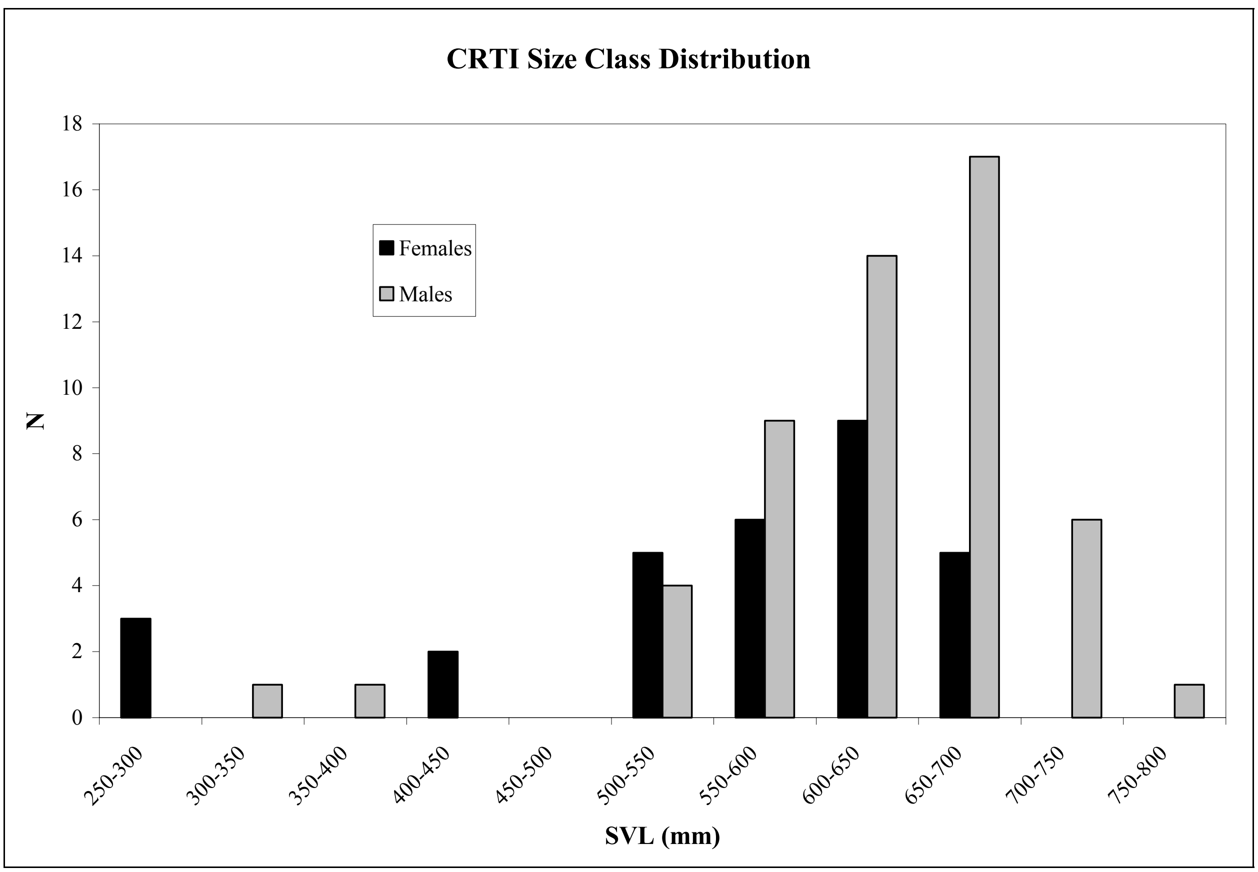


Figure 13. Size class distribution of 83 tiger rattlesnakes (*Crotalus tigris*) from the Stone Canyon development near Oro Valley, Arizona, from 2002-2003. Note the obvious bias towards large adults and the paucity of neonate and juvenile snakes.

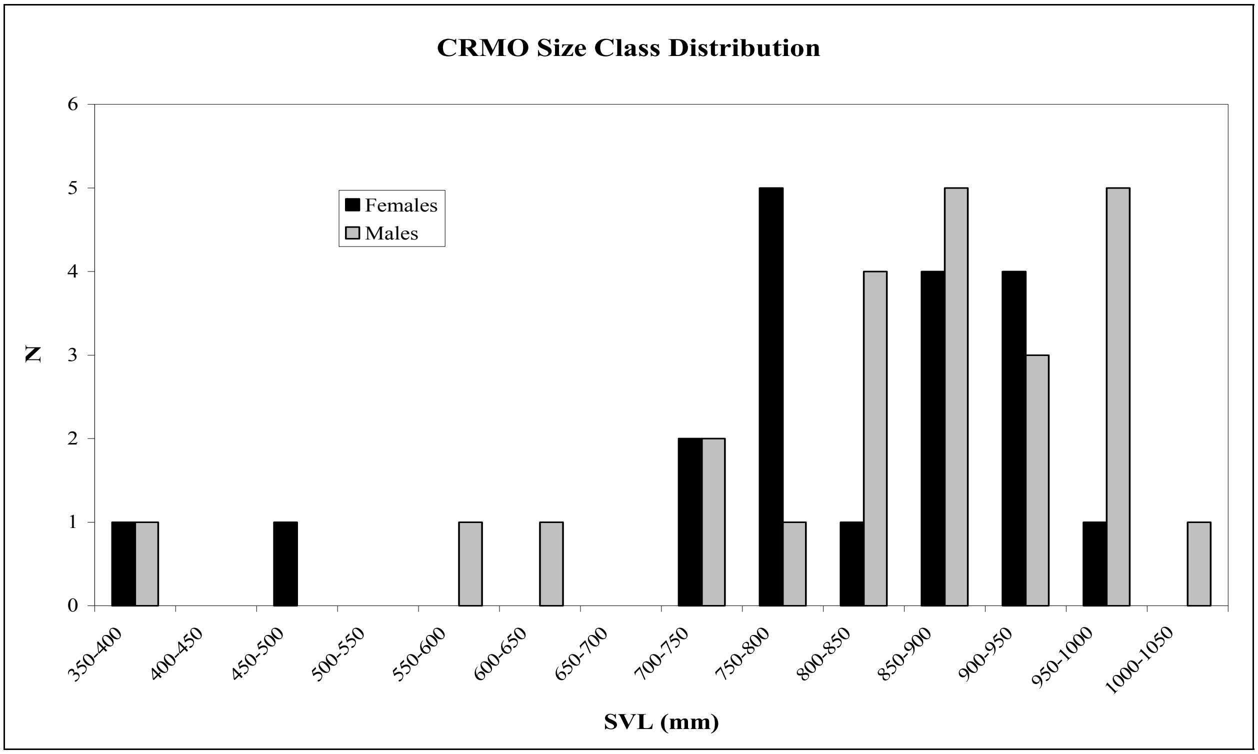


Figure 14. Size class distribution of 42 black-tailed rattlesnakes (*Crotalus molossus*) from the Stone Canyon development site near Oro Valley, Arizona, from 2002-2003. Note the bias towards adults, but not any particular size class for either sex.

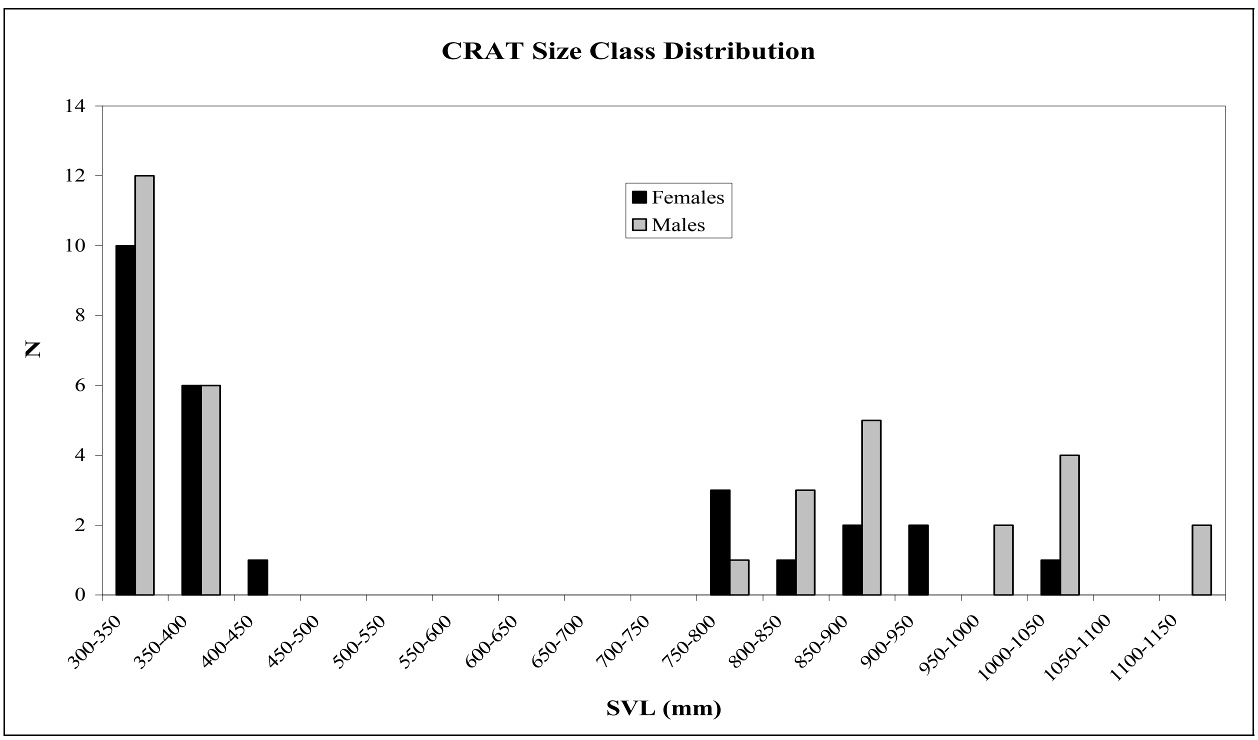


Figure 15. Size class distribution of 61 western diamond-backed rattlesnakes (*Crotalus atrox*) from the Stone Canyon development site near Oro Valley, Arizona, from 2002-2003. Note the bias towards neonate and young-of-the-year snakes.

When monitoring effects of environmental change on wildlife, biologists tend to focus on more traditional parameters such as population size. We contend that demographic traits such as age class or body size distributions may in fact be more informative, especially given the fact that accurate population size estimates can be difficult obtain. Therefore, our datasets pertaining to age and body size for several species are likely to be of importance in determining potential effects of urban development at the population level. The fact that we now have baseline data on a variety of species, each with unique life history characteristics leading to potential differences in vulnerability to disturbance, increases our ability to detect species-specific effects of development.

Larger individuals tend to be more conspicuous, which may be one reason why we generally tend to find much larger numbers adult snakes and lizards. In the case of venomous snakes, such as the rattlesnakes we studied, there may be important advantages of being large. For example, a large rattlesnake is probably safe from all but the largest predators, because it presents a formidable threat. However, when the predator is man, larger size leading to increased probability of detection may be a serious disadvantage. One study on twin-spotted rattlesnakes, funded by AGFD, showed that snakes from a heavily poached population were significantly smaller than snakes from unhunted populations (Prival et al. 1999). It is not unreasonable to predict that large individual rattlesnakes will decrease in numbers as more and more people come to live in the area, resulting in increased persecution of rattlesnakes, a species group that is known to be heavily persecuted (Arena et al. 1995).

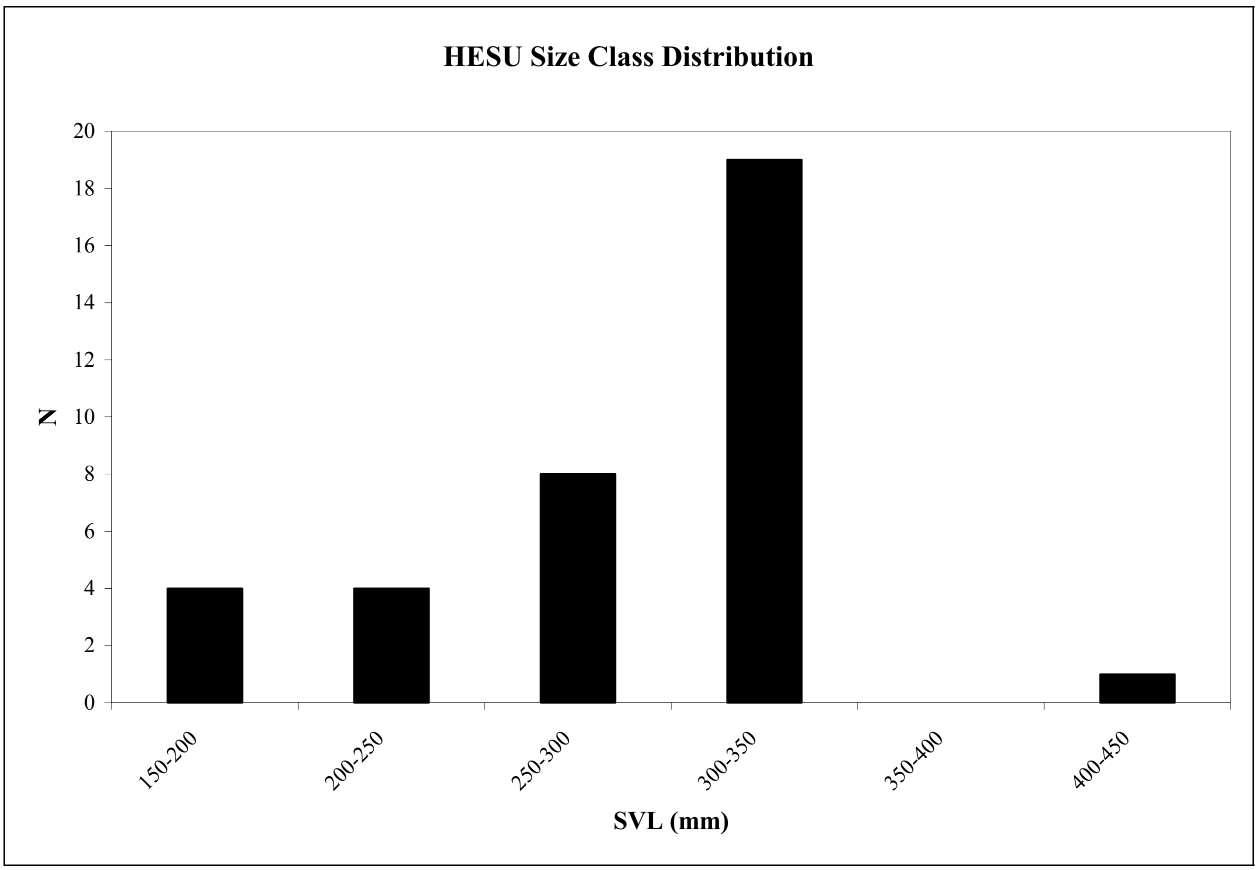


Figure 16. Size class distribution of 36 Gila monsters (*Heloderma suspectum*) from the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. Note the relatively large number of presumably subadult lizards, which is in contrast to size class distributions of three sympatric rattlesnakes species in Figures 13-15.

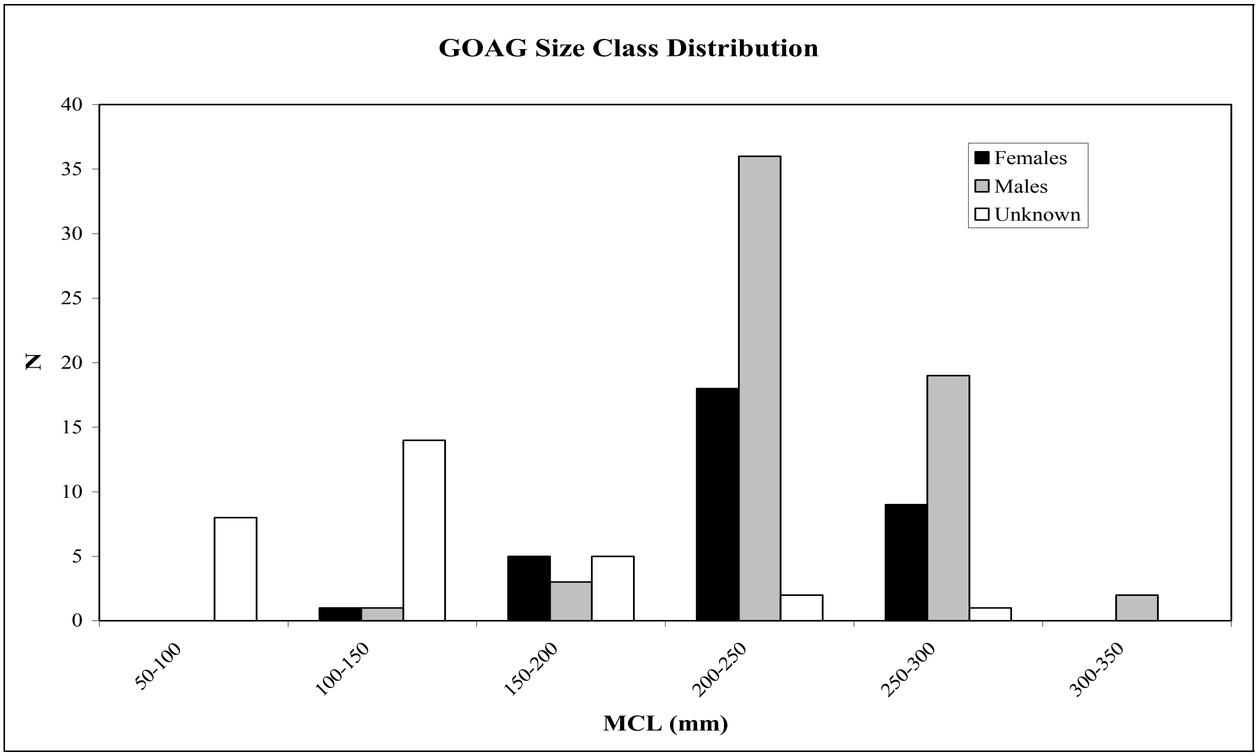


Figure 17. Size class distribution of 124 desert tortoises (*Gopherus agassizii*) from the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003. Note the relatively large number of individuals that could not be reliably sexed, indicating that they are probably not yet reproductively mature.

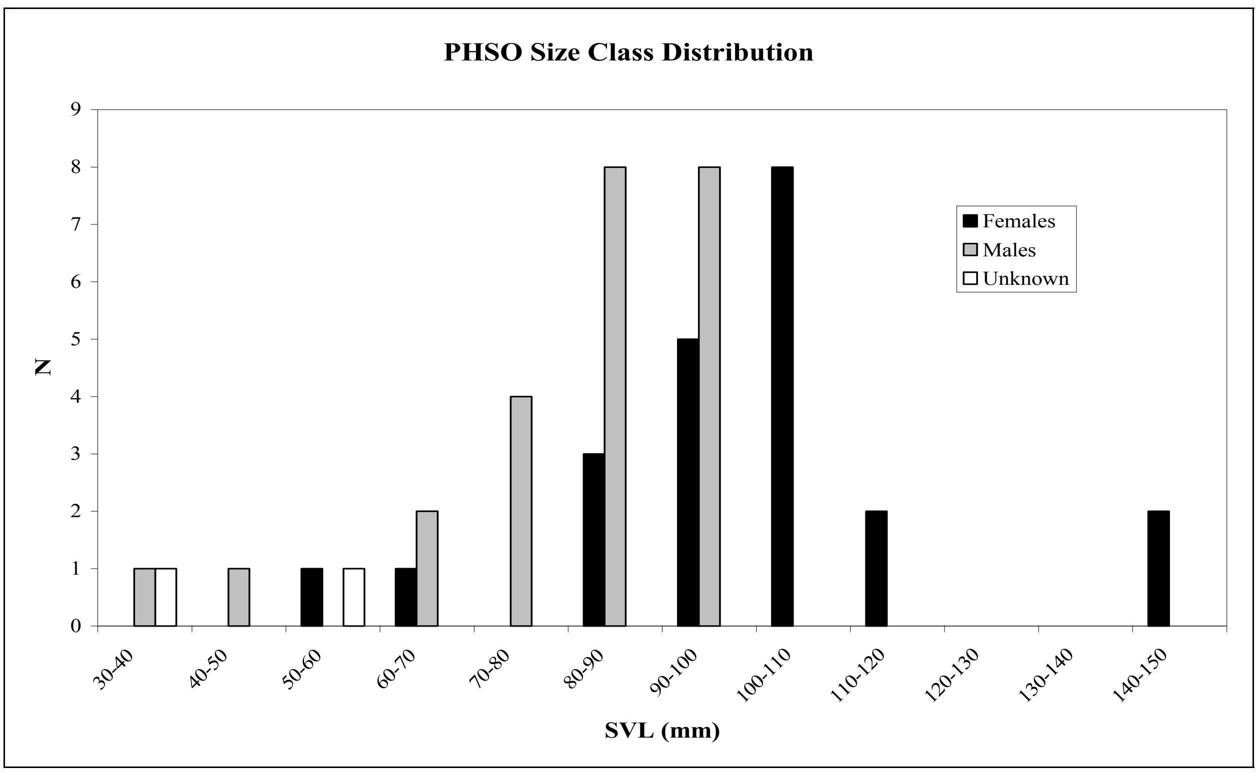


Figure 18. Size class distribution of 48 regal horned lizards (*Phryonsoma solare*) from the Stone Canyon development near Oro Valley, Arizona, from 2002-2003. Note the bias towards moderately sized males and large females.

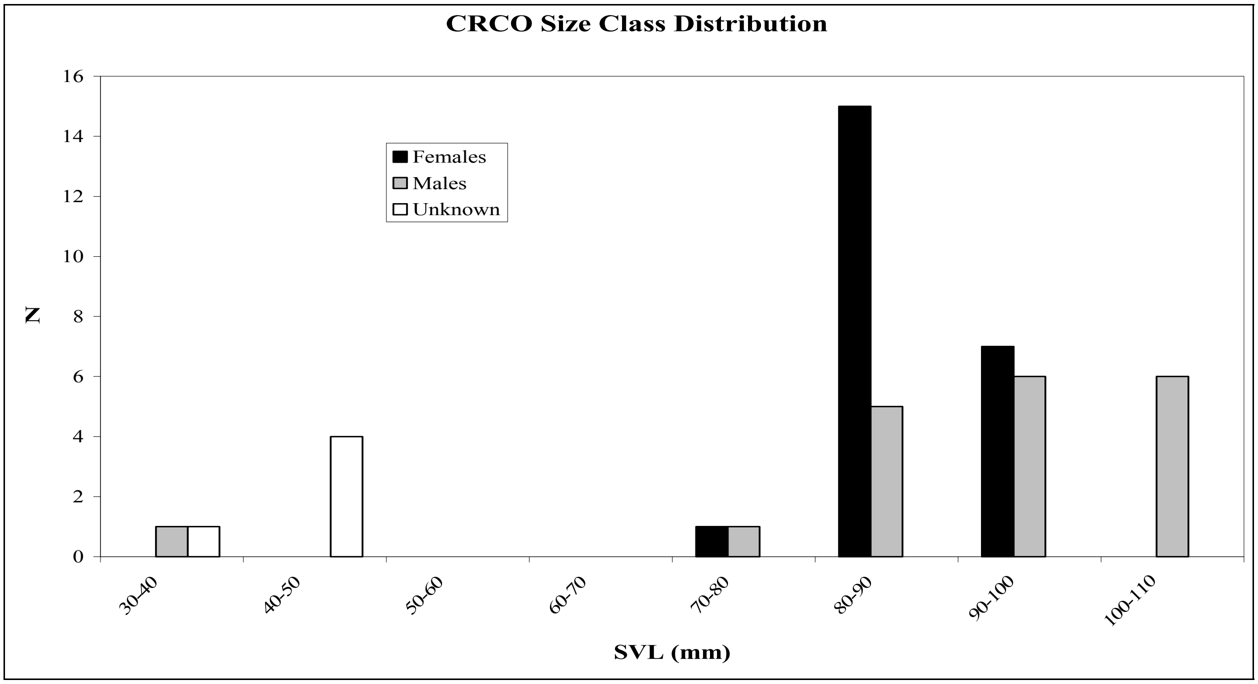


Figure 19. Size class distribution of 46 collared lizards (*Crotaphytus collaris*) from the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

Spatial Ecology of Tiger Rattlesnakes

We captured 84 tiger rattlesnakes (Figure 20), the large majority of which were found while road cruising or conducting golf path surveys (Figure 21).

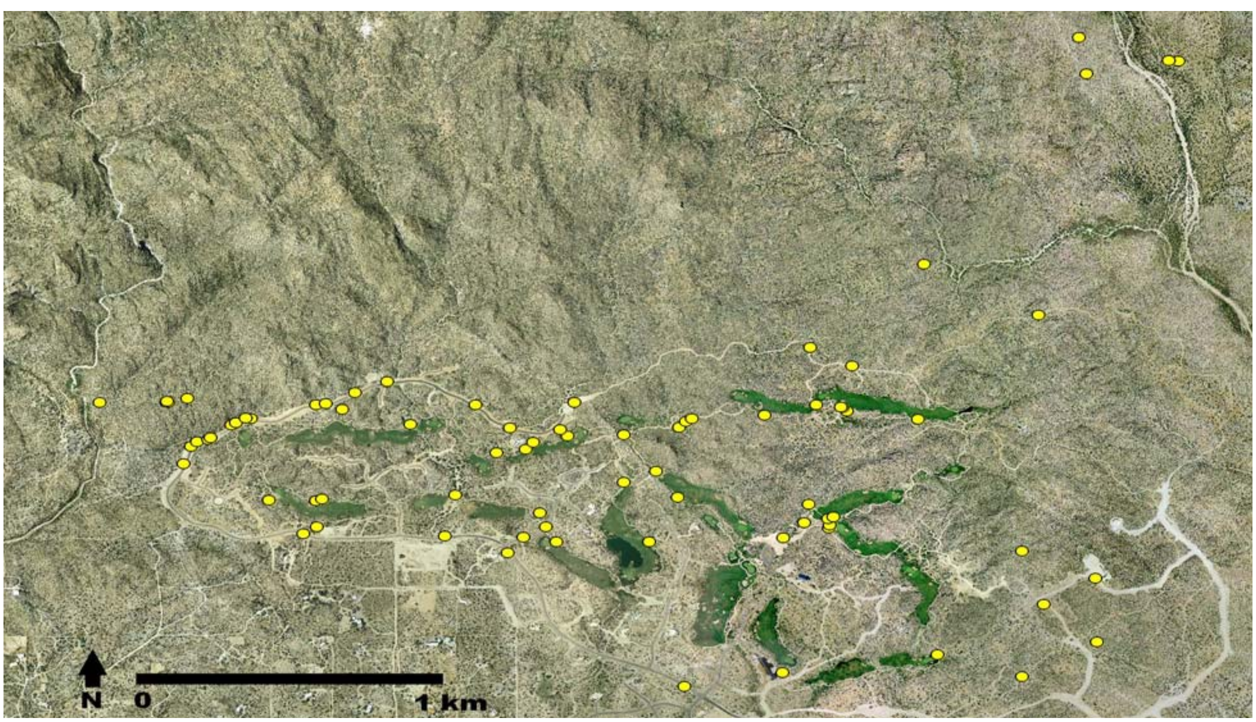


Figure 20. Aerial photograph showing initial capture locations for 84 tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

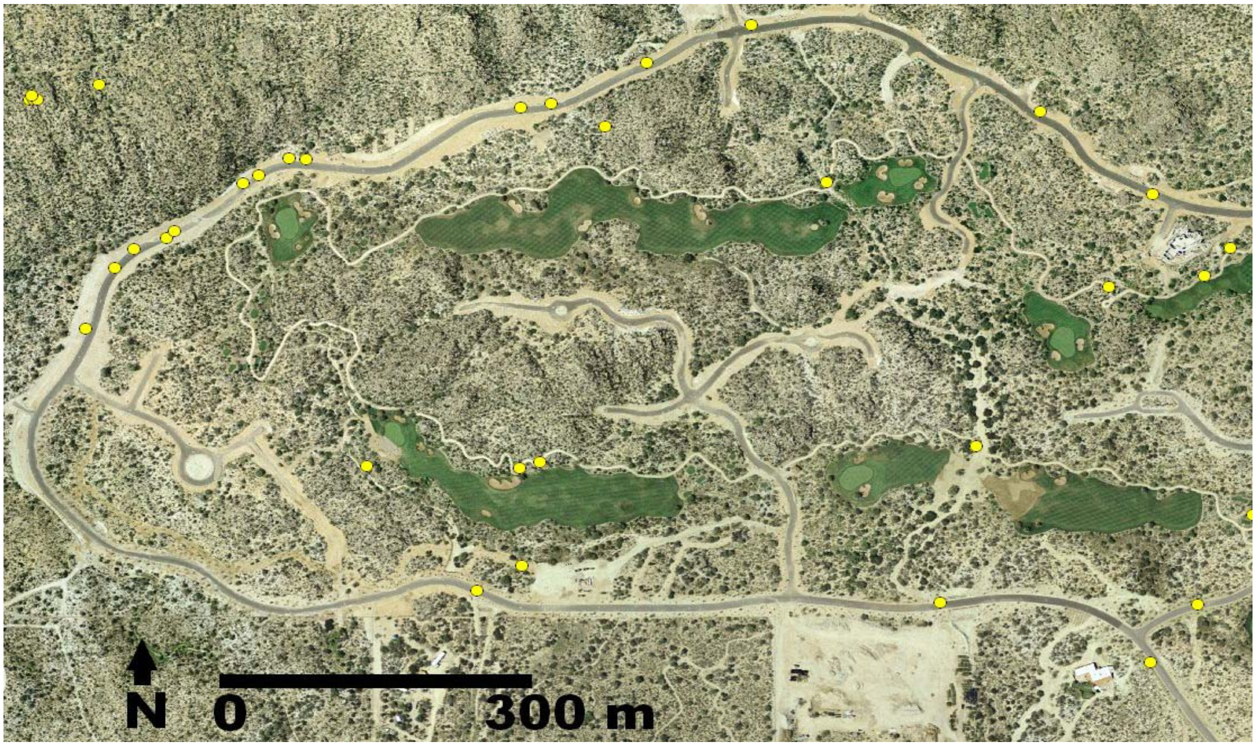


Figure 21. Aerial photograph depicting the large number of tiger rattlesnakes (*Crotalus tigris*) found on roads and golf cart paths at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

We implanted radiotelemeters into a total of 30 tiger rattlesnakes, 15 males and 15 females, which we located 1,008 times (Figure 22).

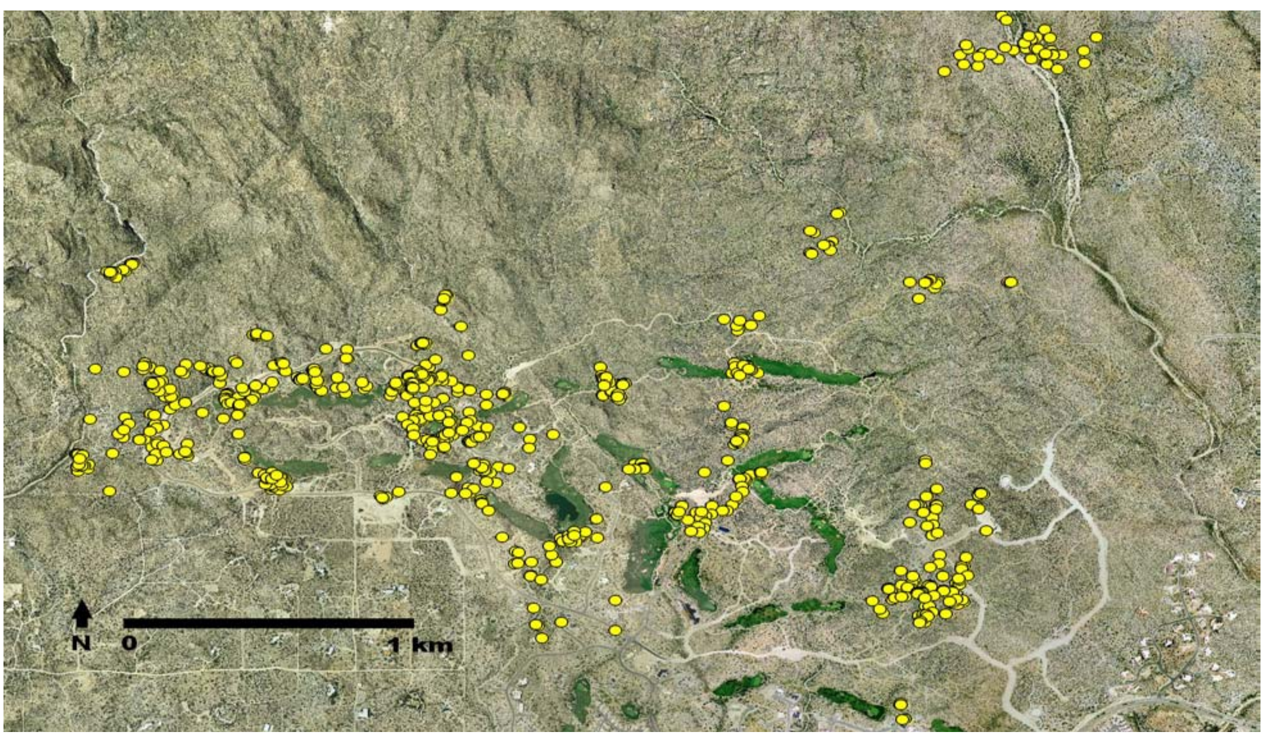


Figure 22. Aerial photograph showing 1,008 radiotracking locations of 30 tiger rattlesnakes (*Crotalus tigris)* at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

We computed several space-use parameters based on the total number of locations for each tiger rattlesnake (Table 16). Due to premature radiotelemetry failure, we were only able to track three snakes for the entire length of the study. We tracked an additional four snakes for a few months in 2002 and all of 2003.

Table 16. Space-use and movement data by sex for all 30 tiger rattlesnakes (*Crotalus tigris*) radiotracked at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

Snake	Sex	n	Begin Date	End Date	Total Distance (m)	Distance/ Day (m)	MCP (ha)	95% AKF (ha)	50% Core (ha)
172	F	26	2002/07/12	2002/10/11	1437	16	85457	18.3	0.7
174	F	46	2002/07/12	2003/04/23	1728	6	53606	12.5	0.3
187	F	31	2002/08/08	2003/05/20	1463	5	49812	14.1	0.7
194	F	30	2002/08/26	2003/05/20	602	2	9060	1.5	0.2
195	F	9	2002/08/30	2002/10/09	106	3	517	0.2	0.03
199	F	66	2002/09/04	2003/09/29	2005	5	11750	19.4	1.4
205	F	67	2002/09/16	2003/09/29	1588	4	34925	8.5	1.0
209	F	64	2002/09/28	2003/09/28	2437	7	91997	31.2	0.2
215	F	37	2003/06/09	2003/09/28	1178	11	7896	1.6	0.4
219	F	24	2003/07/01	2003/09/29	655	7	8683	2.2	0.7
225	F	19	2003/07/18	2003/09/29	785	11	17821	3.8	0.5
240	F	17	2003/07/30	2003/09/28	649	11	9951	2.2	0.1
242	F	14	2003/08/02	3003/09/29	832	14	34161	10.4	2.2
255	F	6	2003/08/23	2003/09/29	480	13	13212	6.7	1.2
262	F	6	2003/09/12	2003/09/29	220	13	4466	2.0	0.3
				Mean ± S.E	**1077 ± 175**	**8.5 ± 1.1**	**3.3 ± 0.8**	**9.0 ± 2.3**	**0.7 ± 0.2**
175	M	99	2002/07/13	2003/09/29	4758	11	95677	18.5	0.8
176	M	49	2002/07/15	2003/09/29	3157	7	71331	14.0	0.4
177	M	52	2002/07/17	2003/09/29	3051	7	57648	13.5	1.5
181	M	18	2002/07/23	2003/04/04	738	3	18883	4.2	1.8
183	M	30	2002/08/02	2003/05/20	1009	3	24681	5.8	0.4
184	M	50	2002/08/02	2003/09/29	5439	13	193886	46.4	2.8
196	M	68	2002/08/31	2003/09/29	4372	11	185818	32.1	2.8
200	M	62	2002/09/09	2003/09/29	4592	15	254597	34.8	2.7
214	M	22	2003/06/07	2003/08/03	636	11	16343	3.5	0.9
217	M	31	2003/06/21	2003/09/29	1724	17	48726	11.3	0.4
222	M	12	2003/07/08	2003/08/13	512	14	11701	4.1	0.2
226	M	18	2003/07/18	2003/09/29	1723	24	53054	10.8	0.6
235	M	11	2003/07/24	2003/09/29	733	11	14007	5.2	0.9
241	M	14	2003/07/31	2003/09/29	1544	26	45004	10.9	2.1
254	M	10	2003/08/22	2003/09/29	735	19	23143	9.2	2.4
				Mean ± S.E	**2315 ± 452**	**12.6 ± 1.7**	**7.4 ± 2.0**	**15.0 ± 3.3**	**1.3 ± 0.2**

On average, males moved over twice as far as females, and their home ranges were over twice as large as females. Males also move farther per day than females, and their 50% core activity areas were roughly twice as large as females. These movement and space-use patterns are similar to those for tiger rattlesnakes that we have studied elsewhere in the Tucson Basin (Goode and Wall 2002).

In order to compare active season (i.e., July 1 – September 30, which roughly corresponds to the summer rainy season), we combined data from both years and then summarized space-use parameters for individuals with > 20 locations (Table 17). Results were similar to those reported above for annual space use and movement patterns in that males again moved over twice as far as females. However, during the active season, male home ranges were three times larger than females and their core activity areas were approximately five times greater than females.

Table 17. Active season space-use and movement data for 7 female and 8 male tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon study site near Oro Valley, Arizona, for the time period from July 1 – September 30 in 2002 and 2003 combined.

Snake	Sex	n	Begin Date	End Date	Total Distance (m)	Distance/ Day (m)	MCP (ha)	95% AKF (ha)	50% Core (ha)
172	F	23	2002/07/12	2002/09/30	708	9	2.1	3.7	0.4
174	F	28	2002/07/12	2002/09/30	1157	14	3.0	2.8	0.3
199	F	28	2003/07/02	2003/09/29	1135	13	4.6	9.1	0.6
205	F	26	2003/07/02	2003/09/29	1003	11	2.6	7.7	0.4
209	F	26	2003/07/02	2003/09/28	706	8	13.5	2.5	0.1
215	F	27	2003/07/02	2003/09/28	988	11	0.8	1.8	0.1
219	F	24	2003/07/01	2003/09/29	655	7	0.9	2.2	0.7
				Mean	**907**	**10.4**	**2.1**	**4.3**	**0.4**
				± S.E	**± 81**	**± 1.0**	**± 0.5**	**± 1.1**	**± 0.1**
175	M	29	2002/07/13	2002/09/30	1478	19	3.3	5.0	0.5
176	M	22	2002/07/15	2002/09/30	906	12	1.6	3.3	0.3
177	M	22	2002/07/17	2002/09/30	1744	23	3.3	6.6	0.5
175	M	31	2003/07/02	2003/09/29	1880	21	4.6	7.4	0.5
184	M	28	2003/07/02	2003/09/29	2437	27	10.3	28.7	0.5
196	M	21	2003/07/01	2003/09/29	2491	28	8.0	16.1	2.1
200	M	24	2003/07/02	2003/09/29	2937	33	12.6	28.1	8.2
217	M	28	2003/07/01	2003/09/29	1651	18	4.8	11.7	0.5
				Mean	**1945**	**22.6**	**6.1**	**13.4**	**1.6**
				± S.E	**± 232**	**± 2.3**	**± 1.4**	**± 3.6**	**± 0.1**

Tiger rattlesnakes are typical of rattlesnake species that have been studied in that males move farther and have larger home range sizes (McCartney et al. 1987). Increased movement by males is probably related to the polygynous mating system exhibited by tiger rattlesnakes (Duvall et al. 1992). The mating system of tiger rattlesnakes is one in which receptive females are a scarce resource in any give year, because they are unable to mate on an annual basis. Males essentially "compete" for females by searching for and finding them. Mating takes place during the summer active season, which corresponds to even greater movement by males relative to females.

Is it possible that development may lead to changes to the mating system? We believe it is possible, if snakes using golf course areas that provide resources that are not normally available are able to store more fat and therefore reproduce more frequently. If females become annual reproducers, the males will no longer have to spend as much time searching for receptive mates. Monitoring the mating system of these serpents as development proceeds is a novel approach that is much different than traditional population size monitoring. The ability to obtain data on the behavioral ecology and compare it in a before-after context is one of the main reasons we incorporated single-species research into our study design.

We also compared active season space-use and movement patterns between years for males (Table 18) and females (Table 19); however, caution should be used in interpreting results due to low sample

Table 18. Active season space-use and movement data for male tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon study site near Oro Valley, Arizona, comparing 2002 with 2003.

Yr	Snake	Sex	n	Begin Date	End Date	Total Distance (m)	Distance/ Day (m)	MCP (ha)	95% AKF (ha)	50% core (ha)
2002	175	M	29	2002/07/13	2002/09/30	1478	19	3.3	5.0	0.5
2002	176	M	22	2002/07/15	2002/09/30	906	12	1.6	1.6	0.3
2002	177	M	22	2002/07/17	2002/09/30	1744	23	3.3	3.3	0.5
					Mean	**1376**	**18.0**	**2.8**	**5.0**	**0.4**
					± S.E.	**± 247**	**± 3.2**	**± 0.6**	**± 1.0**	**± 0.1**
2003	175	M	31	2003/07/02	2003/09/29	1880	21	4.6	7.4	0.5
2003	184	M	28	2003/07/02	2003/09/29	2437	27	10.3	28.7	0.5
2003	196	M	21	2003/07/01	2003/09/29	2491	28	8.0	16.1	2.1
2003	200	M	24	2003/07/02	2003/09/29	2973	33	12.6	28.1	8.1
2003	217	M	28	2003/07/01	2003/09/29	1651	18	4.8	11.7	0.5
					Mean	**2286**	**25.4**	**8.1**	**18.4**	**2.3**
					± S.E	**± 235**	**± 2.7**	**± 1.5**	**± 4.3**	**± 1.5**

Table 19. Active season space-use and movement data for female tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon study site near Oro Valley, Arizona, comparing 2002 with 2003.

Yr	Snake	Sex	n	Begin Date	End Date	Total Distance (m)	Distance/ Day (m)	MCP (ha)	95% AKF (ha)	50% core area
2002	172	F	23	2002/07/12	2002/09/30	708	9	2.1	3.7	0.4
2002	174	F	28	2002/07/12	2002/09/30	1157	14	3.0	2.8	0.3
					Mean	**932**	**11.5**	**2.5**	**3.3**	**0.3**
					± S.E	**± 225**	**± 2.5**	**± 0.5**	**± 0.5**	**± 0.1**
2003	199	F	28	2003/07/02	2003/09/29	1135	13	4.6	9.1	0.6
2003	205	F	26	2003/07/02	2003/09/29	1003	11	2.6	7.7	0.4
2003	209	F	26	2003/07/02	2003/09/28	706	88	1.3	2.5	0.1
2003	215	F	27	2003/07/02	2003/09/28	988	11	7.7	1.8	0.1
2003	219	F	24	2003/07/01	2003/09/29	655	7	0.9	22.3	0.7
					Mean	**897**	**10.0**	**2.0**	**4.7**	**0.4**
					± S.E	**± 93**	**± 1.1**	**± 0.7**	**± 1.5**	**± 0.1**

sizes. During the monsoon season of 2003, male tiger rattlesnakes moved greater total distance and distance per day than they did during the monsoon season of 2002. Males also had much larger home ranges and core activity areas in 2003. Tiger rattlesnakes are known to move farther and more often during years with higher precipitation (Goode and Wall 2002). We maintained three rain gauges at the Stone Canyon study site, which were checked after every substantial rainfall event. Our data indicate that there was very little difference in amount of total summer rainfall between years (Figure 23), although rainfall was distributed differently across July, August and September (Figure 24).

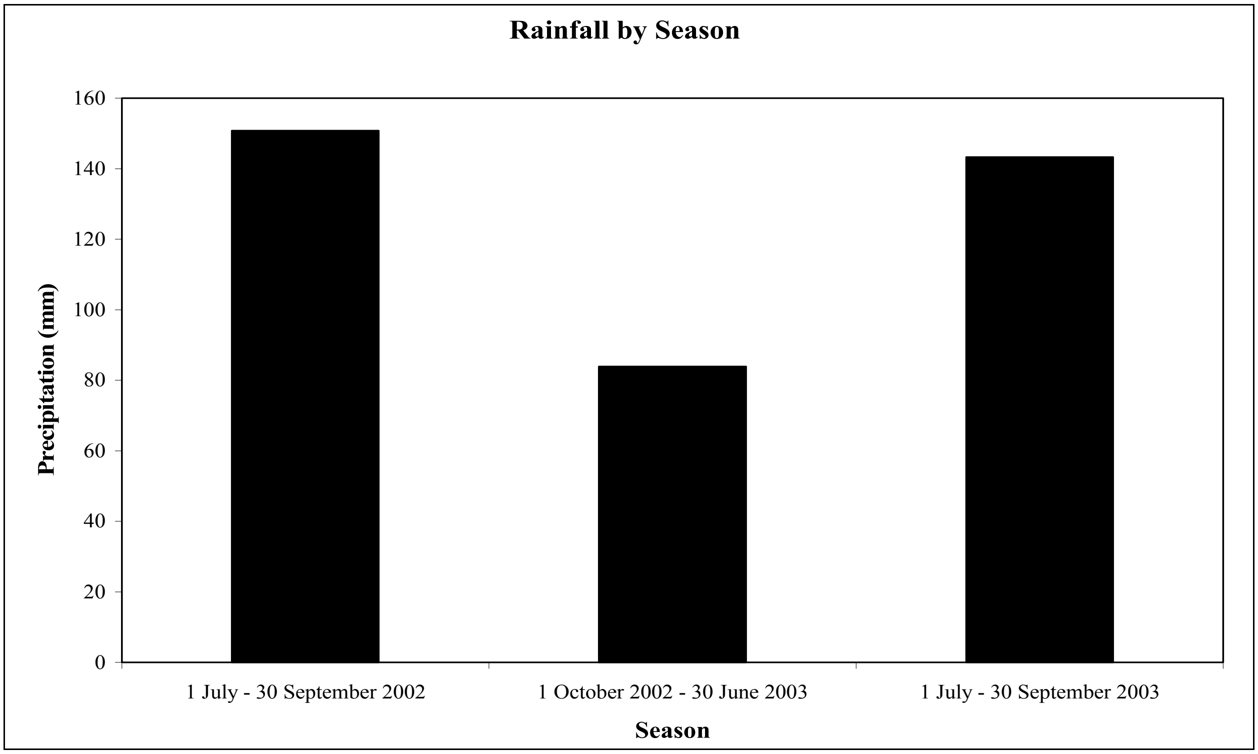


Figure 23. Rainfall by "season" (summer monsoon and intervening "winter" rains) for 2002 and 2003 recorded and averaged from three rain gauges placed at different locations throughout the Stone Canyon study site near Oro Valley, Arizona.

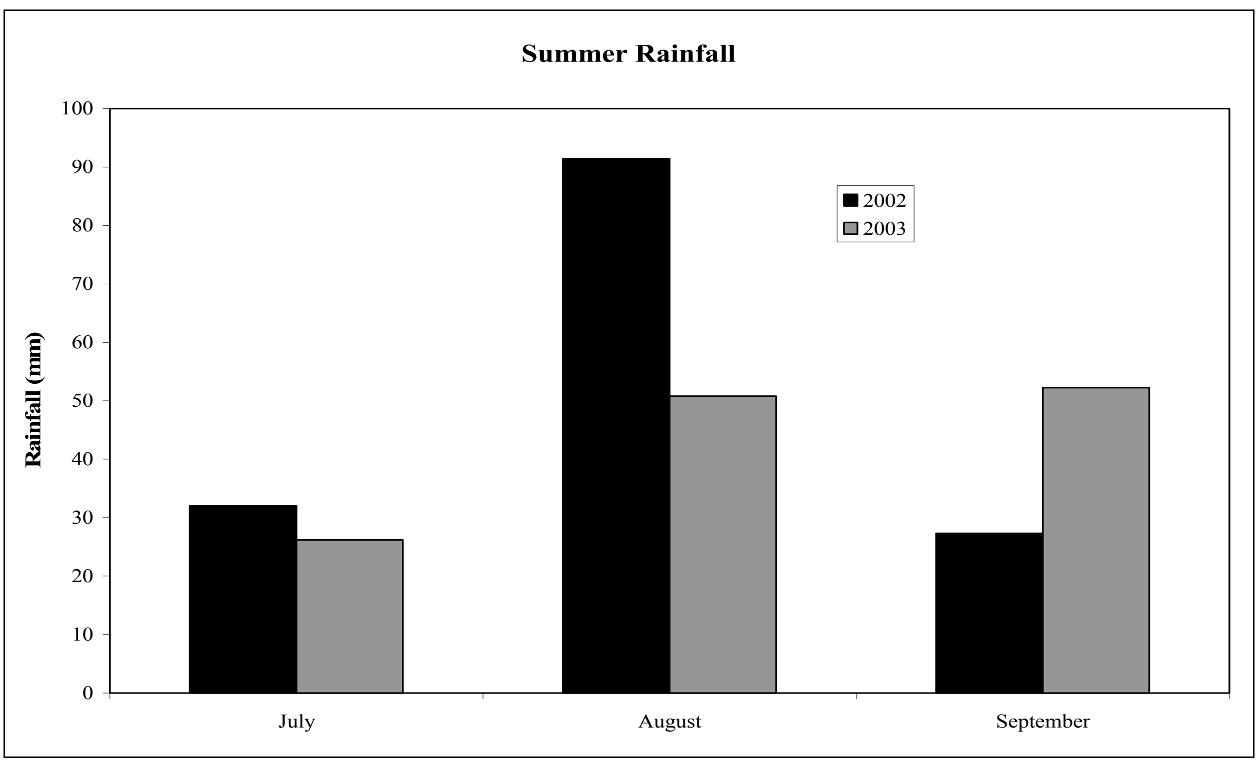


Figure 24. Rainfall per month of the summer monsoon season for 2002 and 2003 recorded and averaged from three rain gauges placed at different locations throughout the Stone Canyon study site near Oro Valley, Arizona.

Monsoon rainfall (i.e., July-September) was average (148 mm) in both years. However, "winter" rains were only 50% of average (161 mm) in winter of 2002-2003. We conclude that rainfall was probably not a determining factor in observed differences in movement patterns. A more likely explanation is that sample size was greater and the length of the tracking period was longer in 2003. More data are required to more thoroughly examine annual differences in movement patterns and space use.

Our main goal was to examine movement patterns and space use relative to development. We plotted minimum convex polygons for all 30 tiger rattlesnakes (Figure 25). The majority of snakes established home ranges that included parts of the golf course and housing development. A smaller number of snake home ranges did not include golf course and housing areas.

As the development progresses, tiger rattlesnakes whose home ranges include the golf course and future residential areas will likely be encountered more frequently by humans. Some will turn up in peoples' back yards, and others will be encountered on road ways or by golfers and other people involved in recreational activities. Still others will come in contact with landscapers, pool service personnel and golf course maintenance staff. It will be interesting to see how tiger rattlesnakes react to increased contact with humans. Tiger rattlesnakes are similar to other snake species that have been studied in that they show strong fidelity to their home ranges. We often find snakes in the exact same shelter sites from one year to the next, and they are often there at the same time of the year. Sometimes, we find snakes at locations on the same day, exactly one year later.

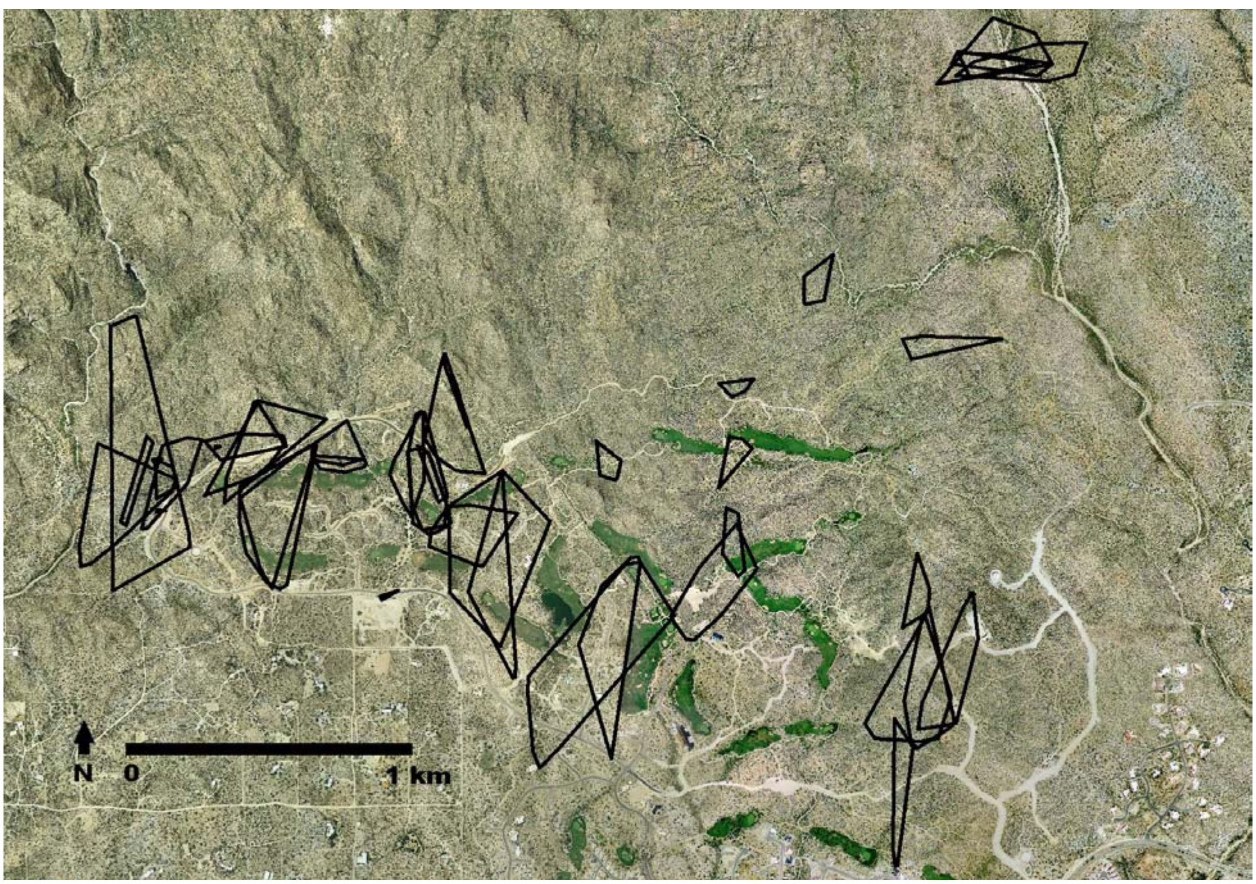


Figure 25. Aerial photograph showing minimum convex polygon home ranges for 30 tiger rattlesnakes tracked between July 2002 and October 2003 at the Stone Canyon development site near Oro Valley, Arizona.

Home ranges of tiger rattlesnakes at Stone Canyon will soon be occupied by houses and people. In some cases, home ranges will include literally dozens of lots with houses, including locations that will become the actual building pad for homes (Figure 26). It will be interesting to see if these snakes continue to use their traditional home ranges, or if they are plastic enough to alter their home range use and location.

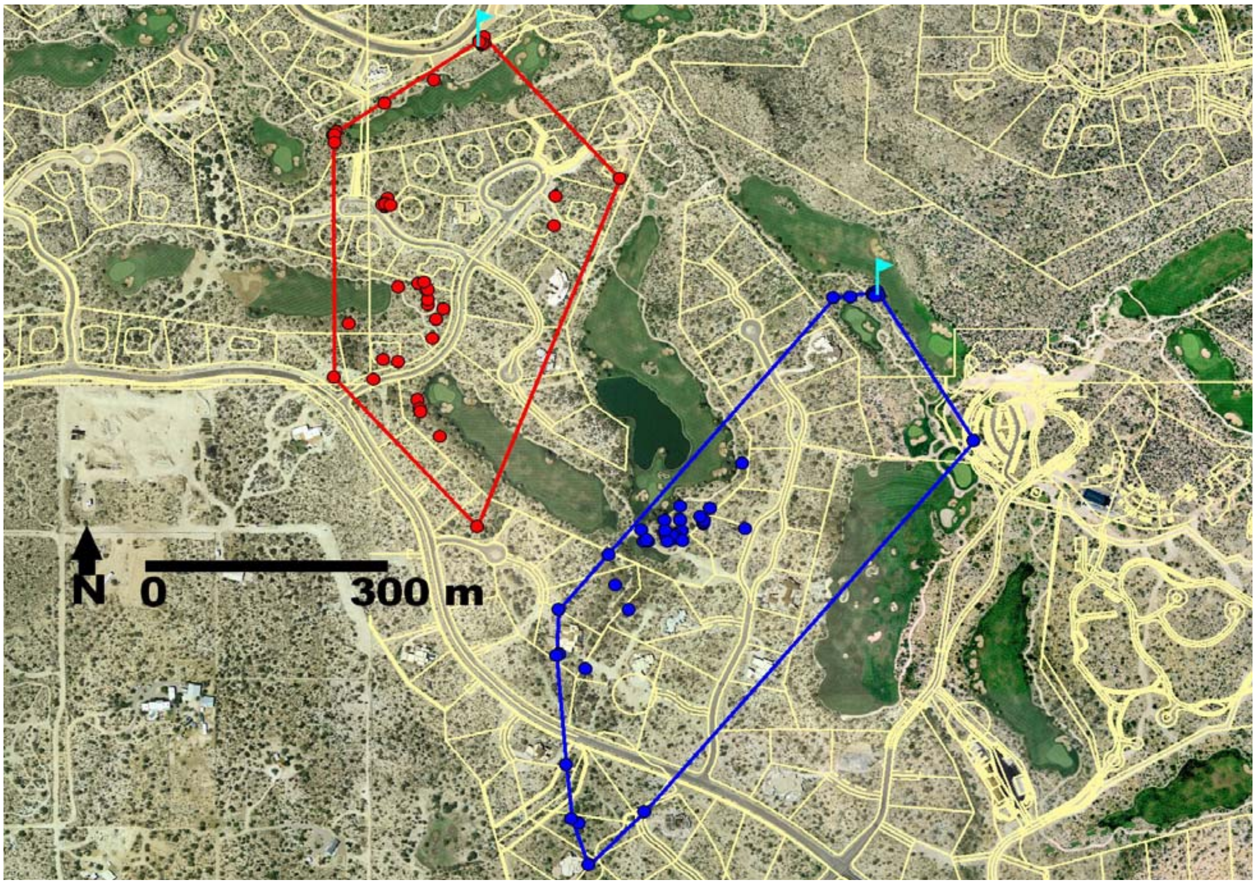


Figure 26. Aerial photograph showing minimum convex polygon home ranges of two tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon study site near Oro Valley, Arizona (2003), that included lots that are either already developed, in the process of being developed, or will be developed in the future.

Some tiger rattlesnake home ranges include areas of the development that will become a large resort (Figure 27). Not only will their chances of encountering humans dramatically increase after the site is developed, they will also lose a significant amount of otherwise useable habitat. The footprint of the main resort and associated structures comprises a significant proportion of both snakes' home ranges. The question is whether or not enough open space will remain to satisfy the requirement of tiger rattlesnakes. Connectivity of habitat patches will also be important to reduce the amount of time rattlesnakes have to spend moving across unsuitable areas to reach patches. Perhaps the golf course will play an important role in allowing tiger rattlesnakes to persist in the face of increasing human habitation, because vegetation along the golf course is dense due to artificial irrigation.

We have observed tiger rattlesnakes using features of the golf course on numerous occasions. One heavily used part of the golf course is the tee boxes (Figure 28). Tee boxes at the Stone Canyon golf course are comprised of large rocks that have been piled up in order to elevate the tee box. These tee

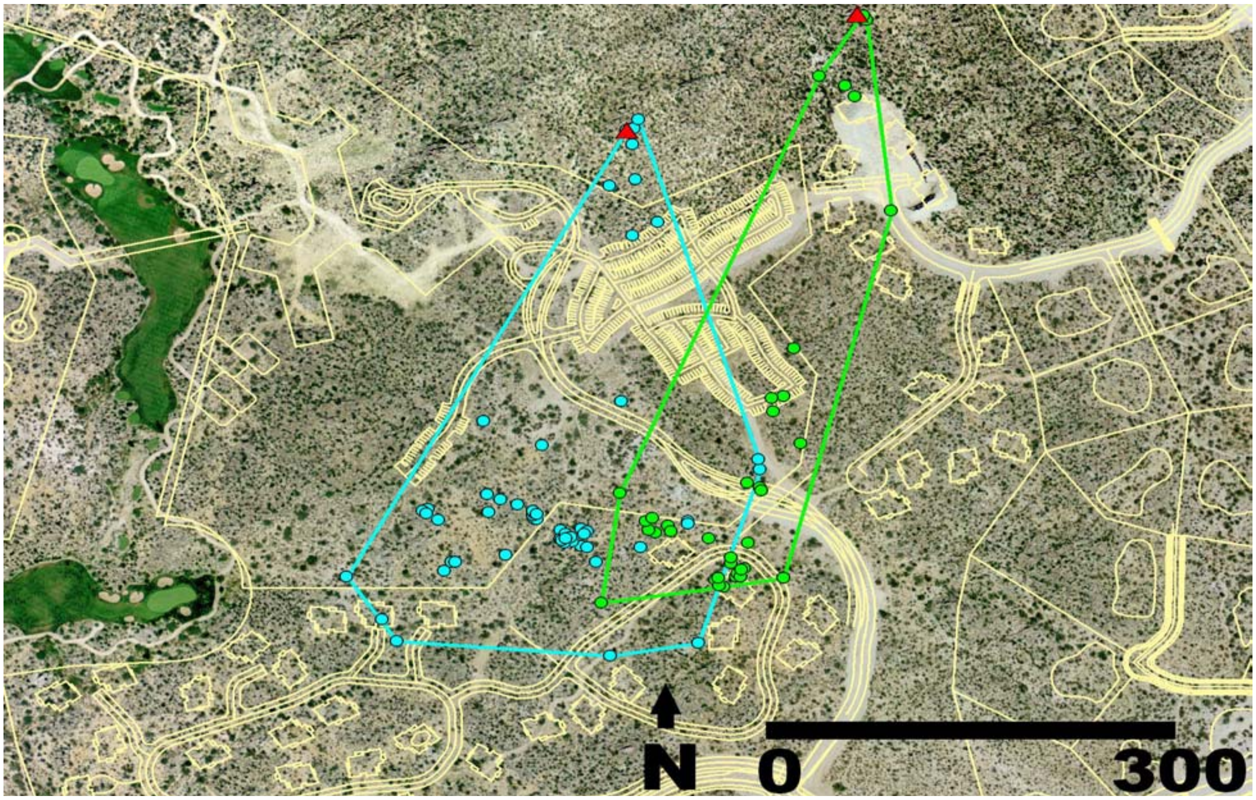


Figure 27. Aerial photograph showing home ranges of two tiger rattlesnakes (*Crotalus tigris*) in 2003 using the area that will become the Ritz-Carlton Resort, a large luxury hotel with numerous outbuildings at the Stone Canyon development site near Oro Valley, Arizona.

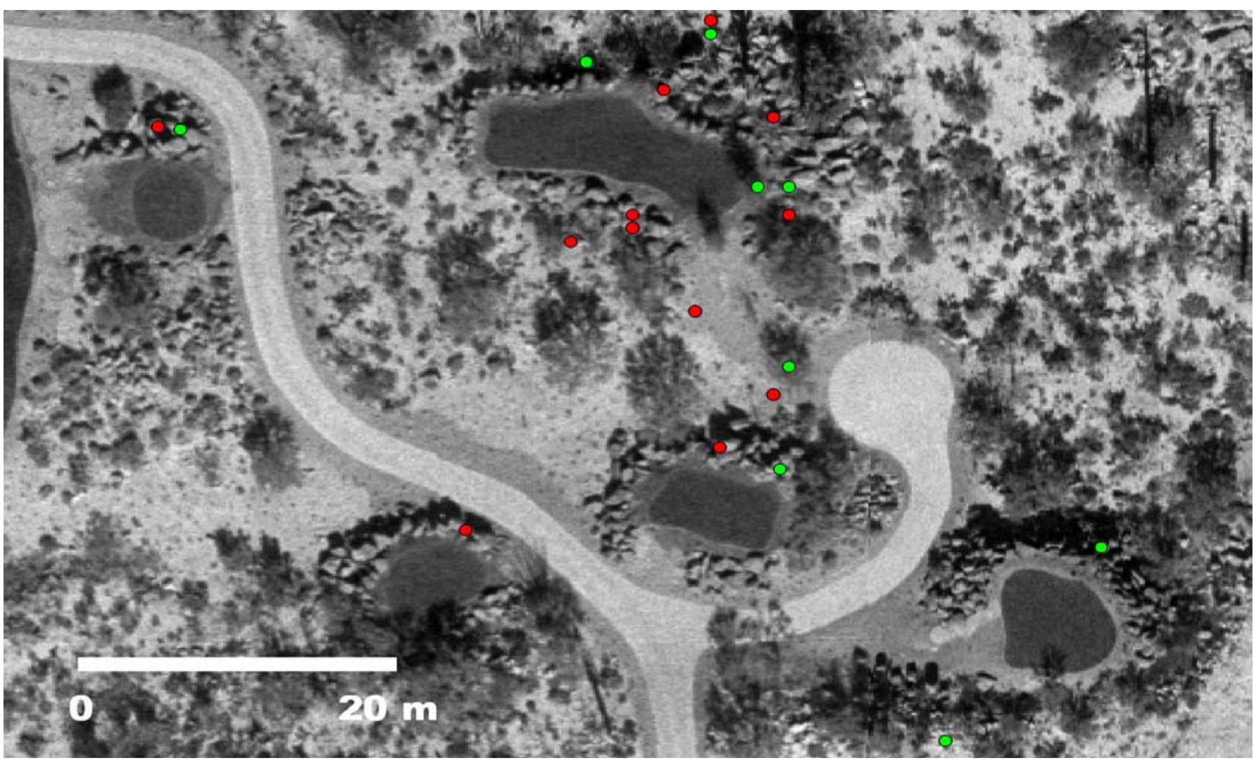


Figure 28. Aerial photograph showing close-up view of tiger rattlesnake (*Crotalus tigris*) locations on golf course tee boxes at the Stone Canyon study site near Oro Valley, Arizona, in 2003.

boxes become artificial rock piles that are backfilled with dirt and then turf is placed over the top of the rock pile. Interstitial spaces between rocks are apparently left behind, because the dirt does not completely fill in between rocks. Rodent activity increases dramatically in the tee boxes, and landscaped vegetation is planted around the edges of the turf and heavily irrigated. Tiger rattlesnakes use these tee boxes in proportions much higher than their availability would predict. We term these tee boxes "tiger rattlesnake condos" because we often find our radiotelemetered snakes using them.

Tiger rattlesnakes also used areas where human activity was high. One example was a snake that spent most of the summer of 2003 in the immediate vicinity of the Stone Canyon Golf Club (Figure 29). On two separate occasions, golf course personnel told us that they saw the snake near the clubhouse, and that golfers regularly observed the snake in the practice area. The snake was obvious, because its rattle was painted, and most people working at the golf course and playing golf are aware of our study. On one occasion, the snake was coiled on the concrete entryway to the clubhouse. The fact that neither golf course personnel nor golfers killed or moved the snake indicates that snakes (even rattlesnakes) are tolerated around the golf course. If this attitude can be maintained as the development grows, it will likely play a critical role in the ability of rattlesnakes to persist in the area. In this vein, we have recently received funding from AGFD to develop and educational program that targets golfers, promoting coexistence of snakes and other herpetofauna inhabiting the site.

Figure 29. Aerial photograph showing several locations of tiger rattlesnake (*Crotalus tigris*) #199 in the vicinity of the Stone Canyon golf course clubhouse at the Stone Canyon study site near Oro Valley, Arizona (August-September 2003). The snake was observed on several occasions by golfers and golf course personnel who reported that they had seen a rattlesnake with a painted rattle. The photograph was taken in 2002.

Tiger rattlesnakes tended to overwinter on rocky slopes above the golf course, however a few individuals overwintered in rock outcrops on the golf course and in areas that will be developed in the future (Figure 30). The destruction of den sites to make way for houses may have an inordinately

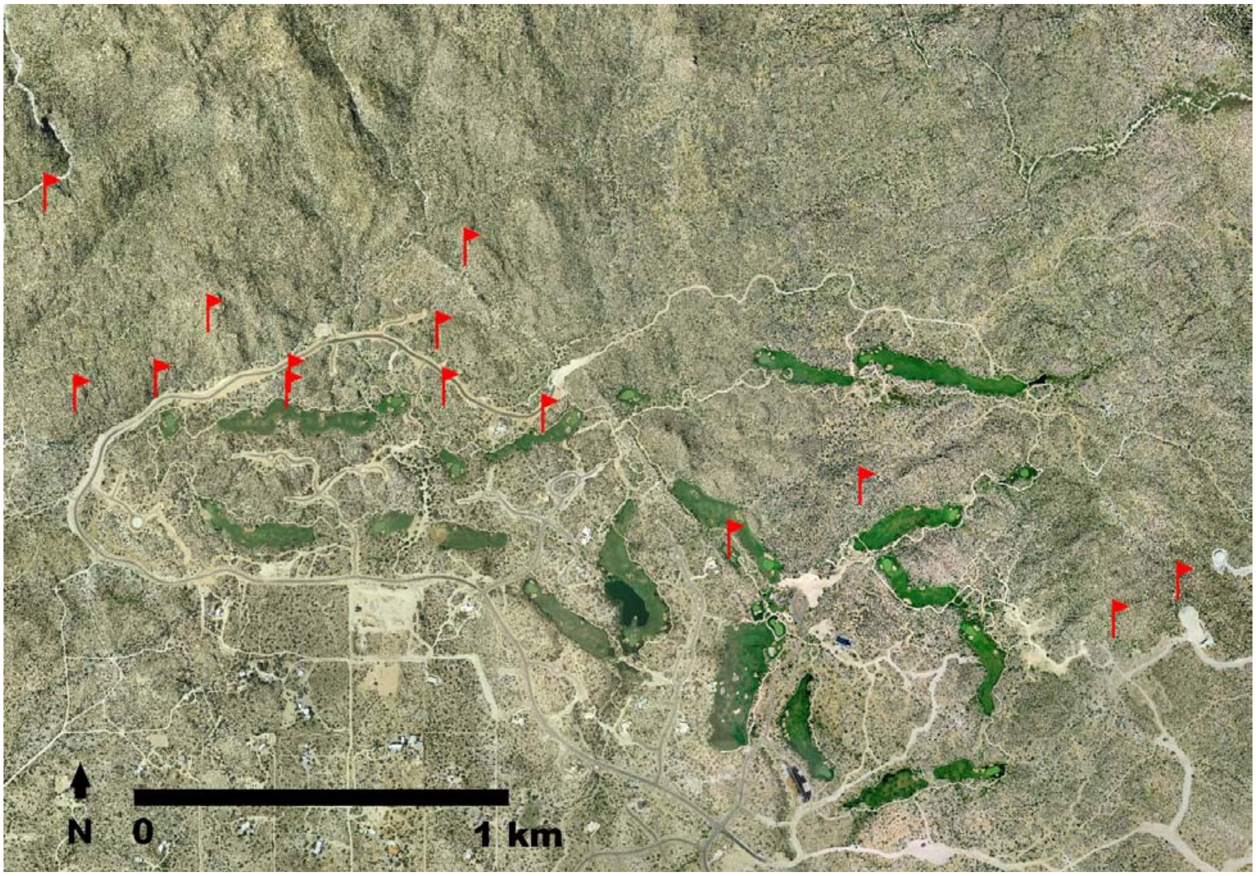


Figure 30. Red flags indicate the sites of tiger rattlesnake (Crotalus tigris) overwintering sites (winter 2002-2003) at the Stone Canyon study site near Oro Valley, Arizona. Some snakes overwintered on or immediately adjacent to the golf course, but most snakes moved up onto rocky slopes above the golf course to spend the winter.

strong impact on snakes. Tiger rattlesnakes tend to use the exact same den sites from year to year, although the presence of suitable habitat for the purposes of surviving the winter do not seem to be limited given the overall rockiness of the area.

Many of the snakes that overwintered north of the golf course moved down onto the course during the summer active season. In order to reach the golf course, snakes had to cross the main road that encircles the golf course (Figure 31). The configuration of the landscape at the Stone Canyon site, with the golf course area essentially serving as a summer activity range separated from a major overwintering area by a road that will be heavily traveled in the future, presents a potential problem that deserves management attention. We know that tiger rattlesnakes are commonly found along this road as previously discussed. We also know that our radiotelemetered snakes frequently cross this road, not only to reach the summer activity range, but as they move about their home ranges (e.g., Figure 32). Based on the fact that many of our radiotelemetered snakes centered their core activity areas on the golf course (Figure 33), using man-made structures and landscaped vegetation, we can only expect the situation to continue. Monitoring tiger rattlesnake use of the golf course and the survival of individuals crossing roads compared to those away from roads will be important.

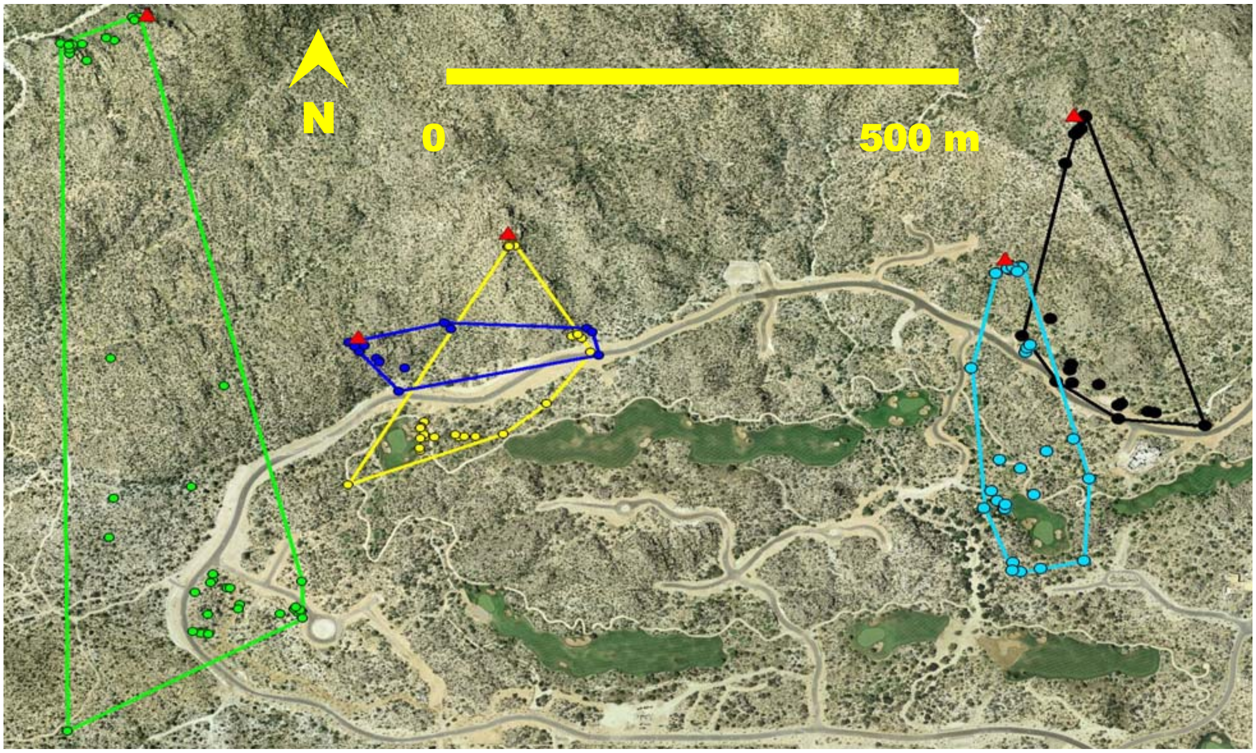


Figure 31. Aerial photograph showing home ranges, tracking locations, and overwintering sites (red triangles) of five tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon development site near Oro Valley, Arizona. Overwintering sites were located on steep rocky slopes above the golf course, and snakes had to cross the main road in order to utilize golf course surroundings.

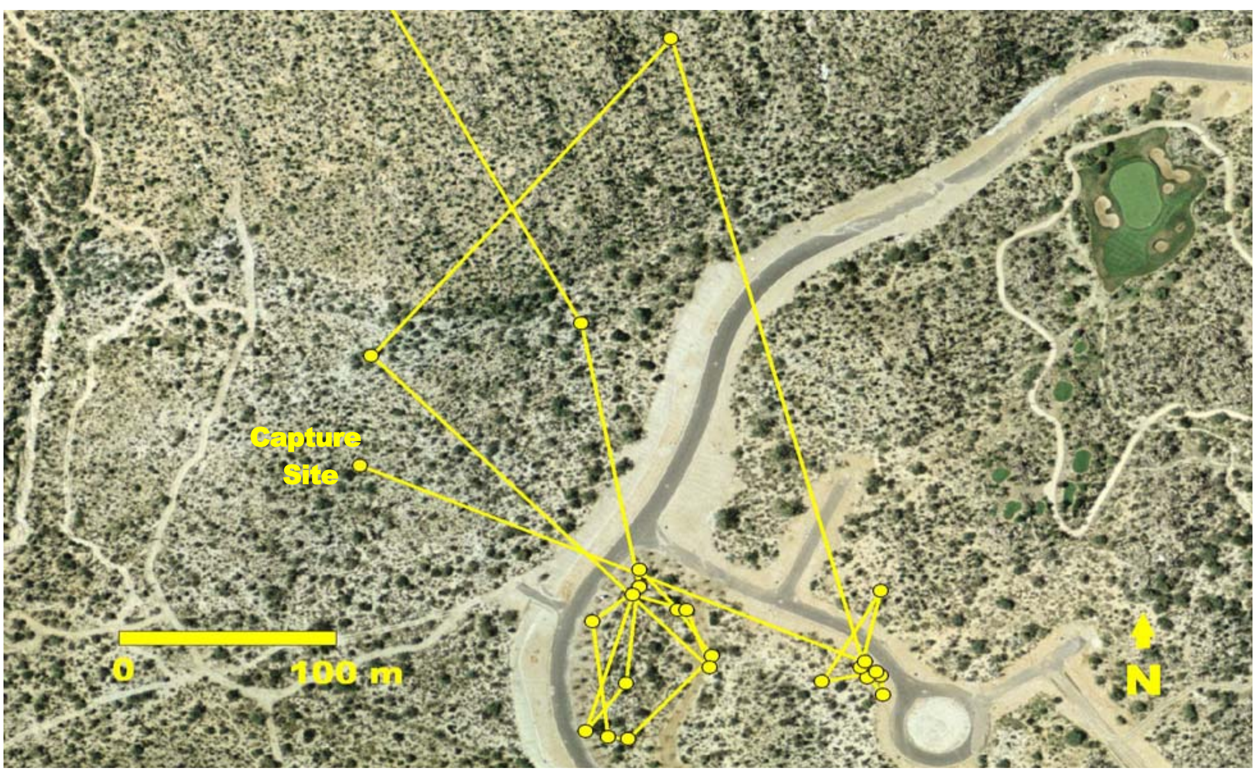


Figure 32. Aerial photograph of an individual tiger rattlesnake (Crotalus tigris) crossing the road multiple times while traversing its home range at the Stone Canyon study area near Oro Valley, Arizona.

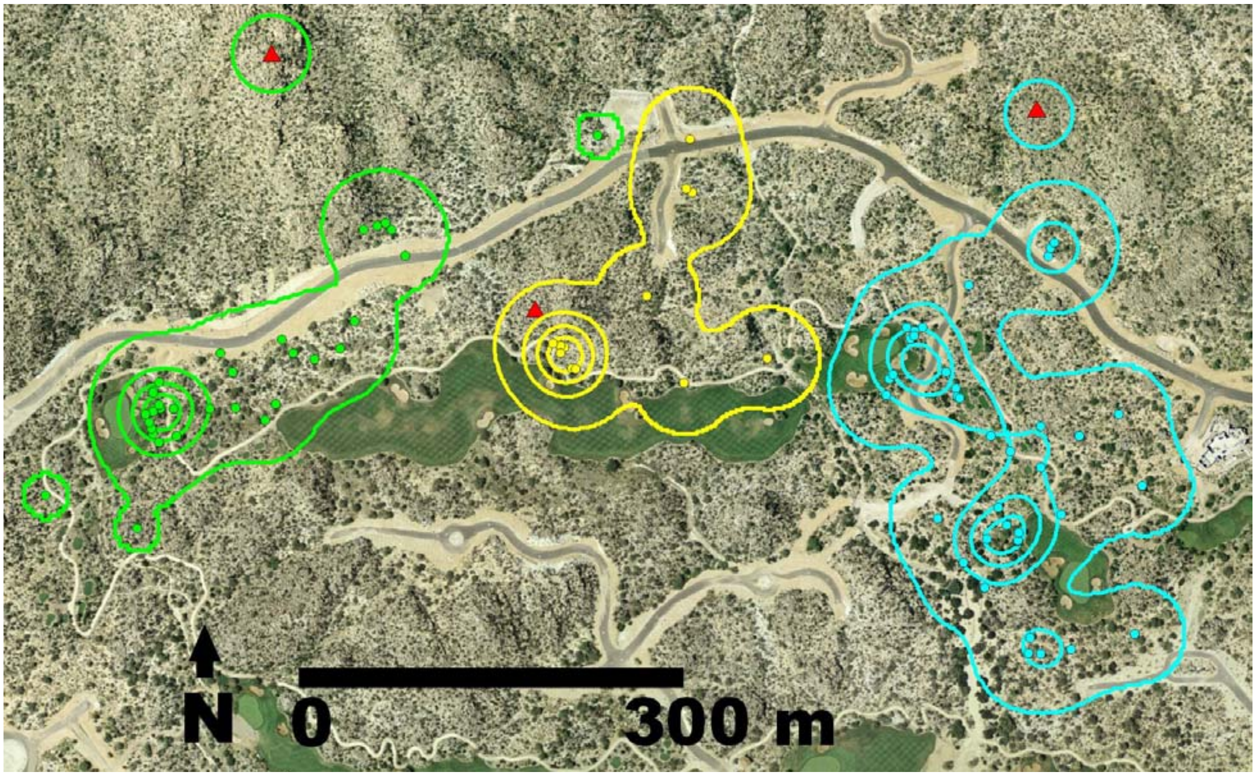


Figure 33. Aerial photograph showing active kernel home ranges of three tiger rattlesnakes (*Crotalus tigris*) at the Stone Canyon study site near Oro Valley, Arizona, in 2003. Red triangles indicate the locations of overwintering sites. Active kernel home ranges consist of four isopleths, with the outermost isopleth corresponding to a 95% probability that a given snake location will fall within its bounds. The innermost isopleth is corresponds to a 10% probability that a given location will fall within its bounds. Because a large number of locations fall into such a small area, it indicates that the snakes are concentrating their activities within this area, which is referred to as a core activity area. The core areas of all three snakes in this photograph are centered on the edges of golf course greens, fairways, and tee boxes where there is plenty of well-irrigated, landscaped vegetation.

During the course of the study, at least two radiotelemetered tiger rattlesnakes were killed, presumably by construction workers. Intentional killing of venomous snakes is not uncommon (Arena et al. 1995) and in urbanized areas may become an important threat. One tiger rattlesnake spent a several days in a man-made rock pile at the edge of an area that had been cleared to crush rock and serve as a general maintenance yard (Figure 34). One day, we found the snake missing its head and rattle. We talked to construction workers at the site, but they did not admit to killing the snake. However, they did say that they often observed rattlesnakes and that many workers killed them on site. The other tiger rattlesnake that we think was killed by construction workers was found dead a few days after construction began on a new home where the snake had been spending time. Although we cannot be sure the snake was killed by construction workers, it seemed likely given the presence of tools, a cement mixer, and other construction materials immediately adjacent to the site where we found the dead snake. It may be that a disproportionate number of snakes die during the construction phase of development compared to the post-development phase when people living in the area are more tolerant of snakes and other wildlife in their surroundings. Indeed, some people move into exurban developments because they consider wildlife, even venomous snakes, an amenity. It is worth mentioning that several radiotelemetered tiger rattlesnakes were lost from one day to the next during the study. Although radiotelemetry failure or natural predation may have been the cause, we feel that is just as likely, if not more so, that these snakes were killed and removed by construction workers.

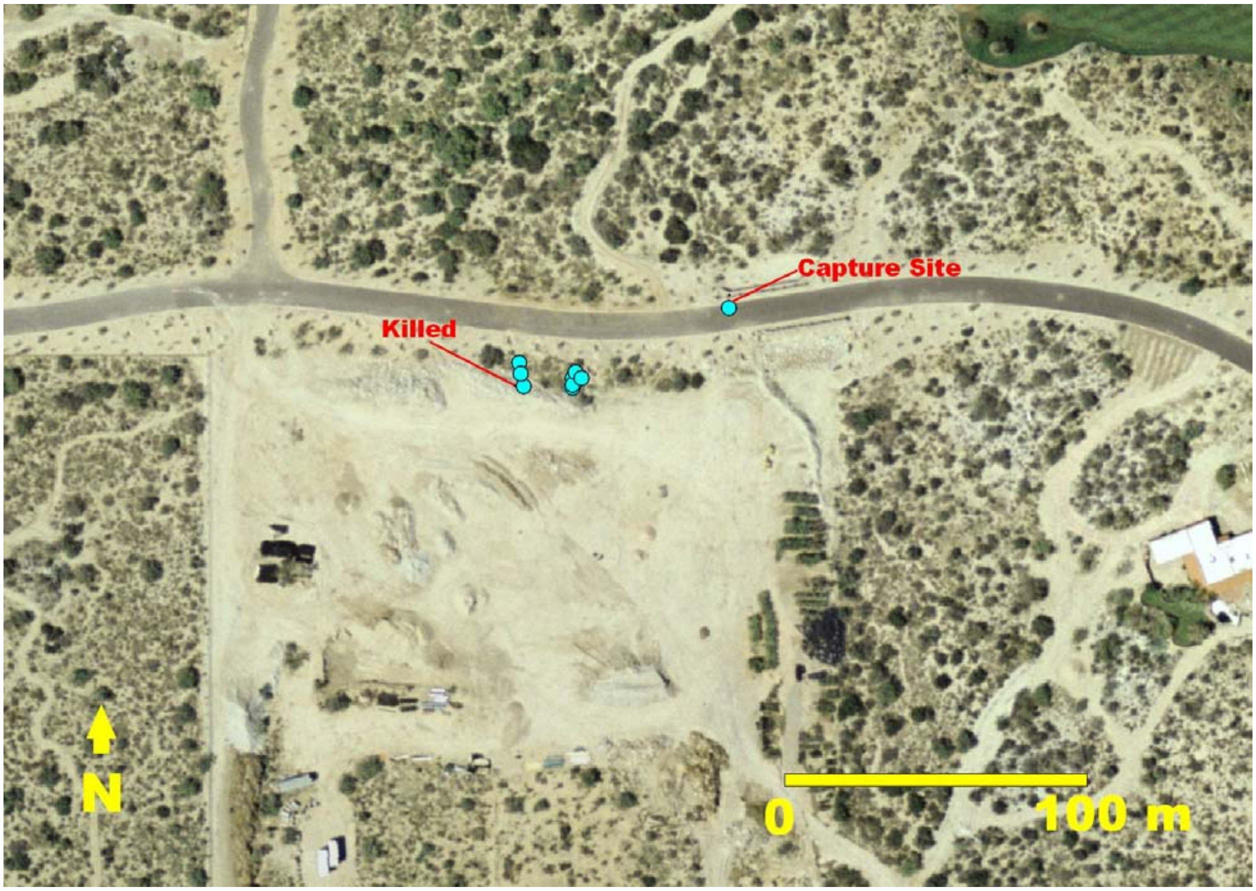


Figure 34. Aerial photograph of the capture site and several locations of a radiotelemetered tiger rattlesnake (Crotalus tigris) that was killed, presumably by construction workers, at the Stone Canyon study site near Oro Valley, Arizona, in 2003.

Potential Golf Course Effects

We investigated a variety of ways in which the golf course may have affected the ecology of various amphibian and reptile species at our study site. For tiger rattlesnakes, we calculated an index of condition by dividing log-transformed SVL data by log-transformed mass to arrive at a measure of mass per unit body length that is presumably related to health. Tiger rattlesnakes captured on the golf course were significantly more massive per unit body length than snakes captured away (> 500 m) from the course ($t = -2.72$, $df = 69$, $p < 0.008$; Figure 35).

A snake that is more massive per unit body length is presumably a healthier snake. Although there are problems with this index, because mass is sensitive to recent feeding events or to reproductive condition in females, it is widely used for snakes. If a snake had an obvious food bolus or was gravid, it was not included in our analyses. Although various factors for which we have no data could possibly account for the observed difference in body condition, we find the results to be intriguing. We will be studying potential effects of golf courses on tiger rattlesnakes, and herpetofauna in general, as part of an AGFD-funded study that began this past summer.

We were unable to make quantitative comparisons of tiger rattlesnake movement patterns between snakes on the course and snakes away from the course, because most of the snakes we followed away from the course were only recently implanted with radiotelemeters.

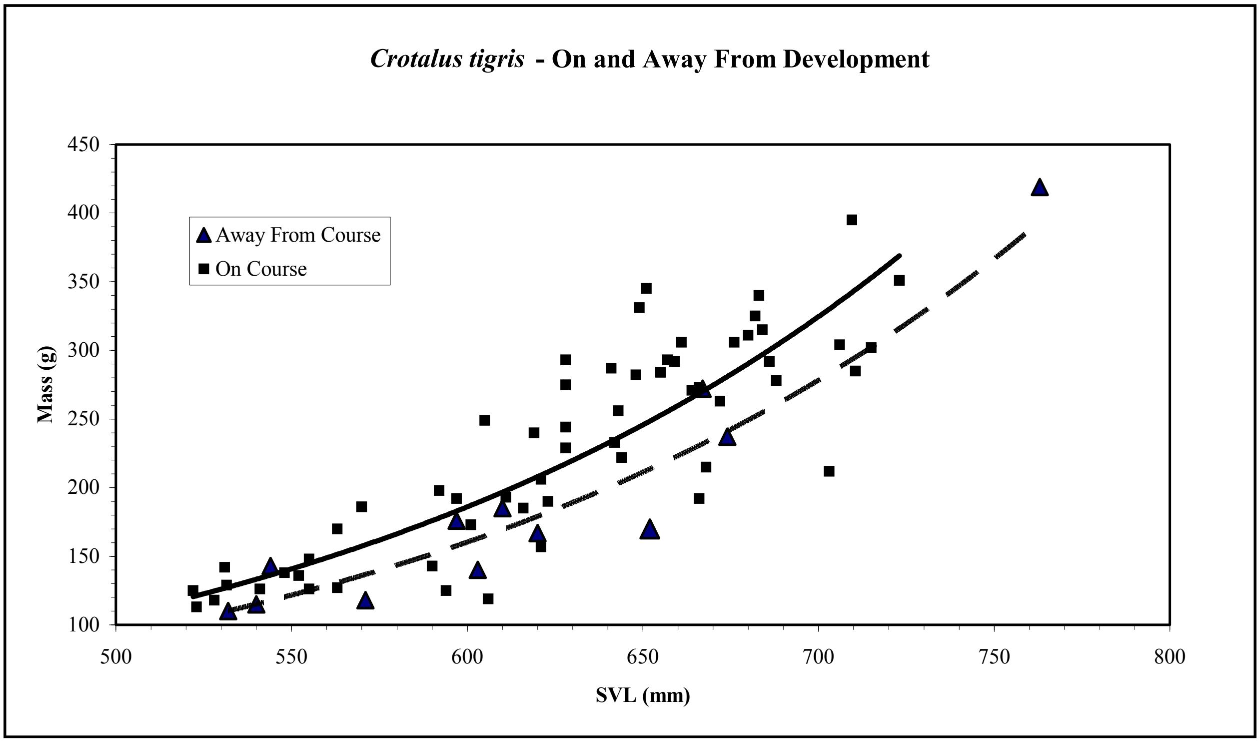


Figure 35. Comparison of body condition index (mass divided by body length) for tiger rattlesnakes (*Crotalus tigris*) from on and away from (> 500m) the golf course at the Stone Canyon study site near Oro Valley, Arizona, from 2002-2003.

We examined patterns of toad distributions relative to the golf course. Based on road cruising and golf path surveys, we found that toads were more prevalent on the golf course during the dry summer season before the onset of the summer rains than away from the golf course. After the rains arrived, toads generally dispersed from the golf course ponds and irrigated areas and were then found more often on roads away from the golf course (Figure 36). This pattern held true for the two common toad species on site, the Sonoran Desert toad (Figure 37) and the red-spotted toad (Figure 38). It appears as if toads are able to extend their above ground activity period by utilizing wetter areas and water sources associated with the golf course. We also observed breeding aggregations on golf course ponds, but tadpoles were only observed in pools away from the golf course, suggesting that golf course ponds provide suitable breeding habitat, but may not be conducive to hatching. Golf course managers do use algaecides in the golf course water hazards, and ponds do contain dense populations of non-native game fish. The effects of chemicals and exotic predators in golf course ponds on toads and other aquatic herpetofuana (i.e., black-necked gartersnakes) deserves increased attention.

Plot Characteristics

Control plots had significantly more relatively flat, open desertscrub than either interior ($t = 4.03$, $df = 15$, $p < 0.001$) or margin ($t = 2.55$, $df = 15$, $p < 0.022$) plots and significantly fewer rock outcrops than interior ($t = -3.88$, $df = 15$, $p < 0.002$) or margin ($t = 2.62$, $df = 15$, $p < 0.019$) plots (Figure 39). Interior plots had more disturbed area, but only four plots had any disturbance at all, and the area affected was relatively small, consisting of short dirt road segments. As discussed above, control plots had significantly more lizards than the other two plot types. The large number of certain common lizards (e.g., *Cnemidophorus tigris, Callisaurus draconoides*) that are associated with open desertscrub is probably what accounted for the observed difference in lizard numbers between plots

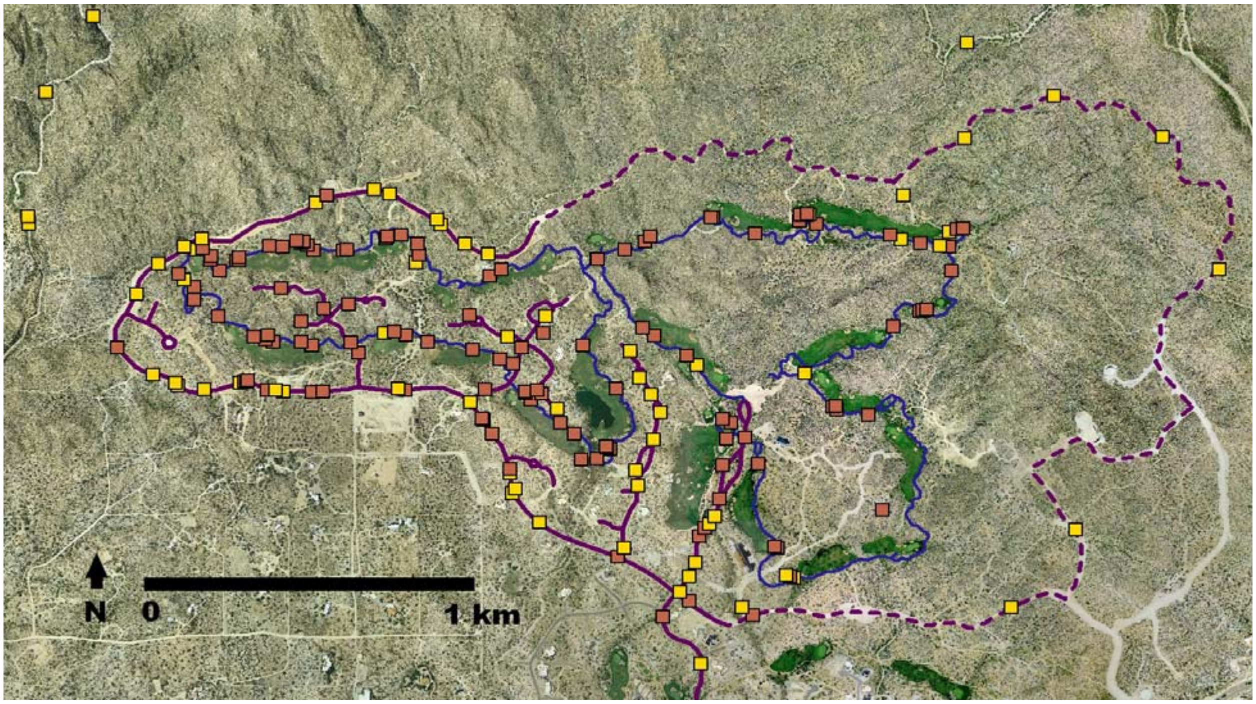


Figure 36. Aerial photograph showing locations of all toads observed (2002-2003). Toads were found more frequently on the golf cart path (brown squares) during the dry months of May and June, and more frequently on roads away from the golf course after monsoon rains began in July (yellow squares).

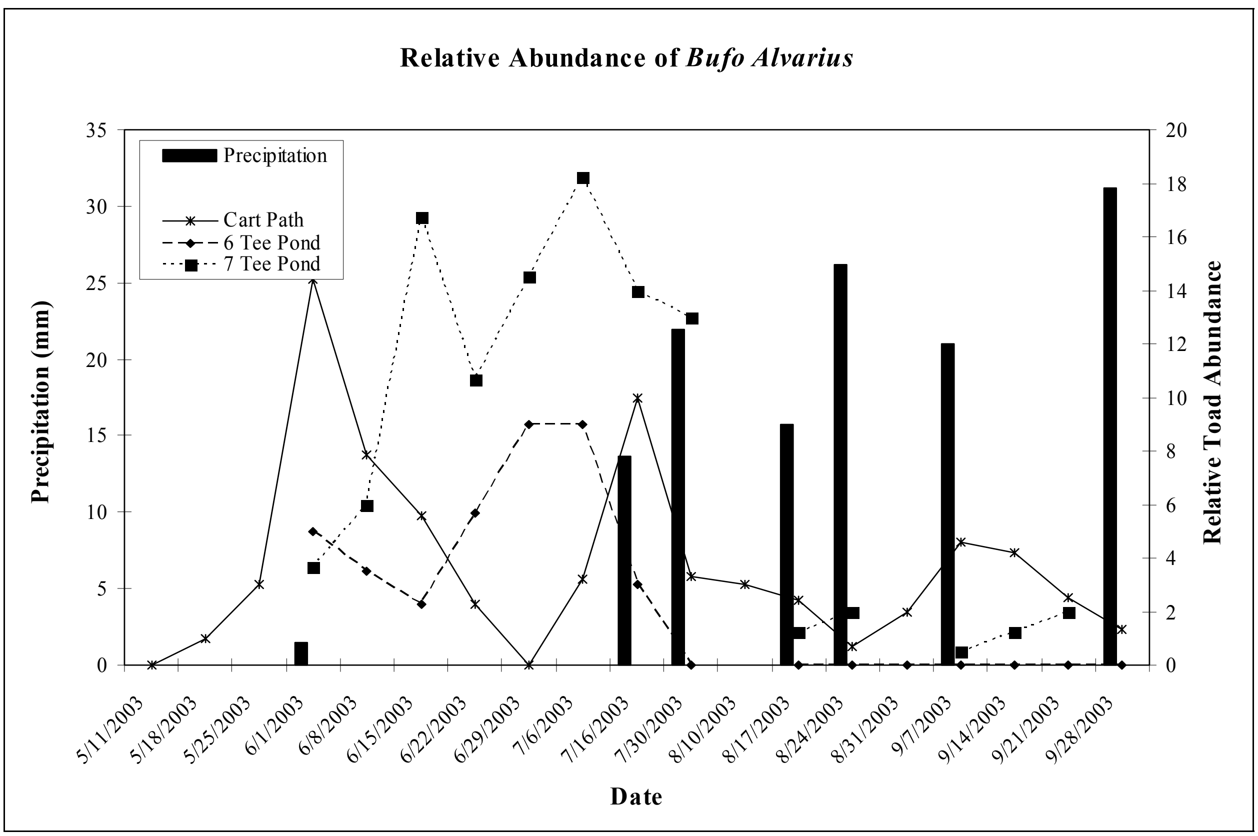


Figure 37. Relative abundance of Sonoran Desert toads (*Bufo alvarius*) by week and rainfall at the Stone Canyon study site near Oro Valley, Arizona, in 2003. Sonoran Desert toads found on the golf paths and in golf course ponds decreases dramatically after the onset of summer rains.

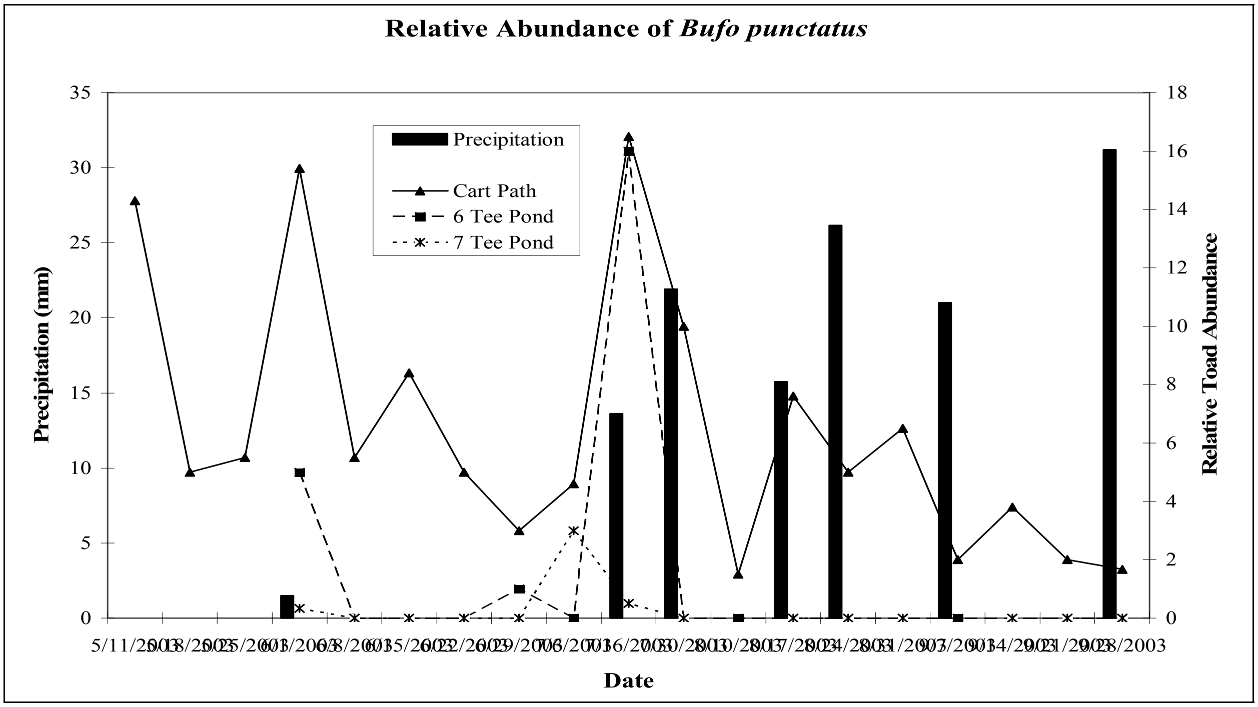


Figure 38. Relative abundance of red-spotted toads (*Bufo punctatus*) by week and rainfall at the Stone Canyon study site near Oro Valley, Arizona, in 2003.

types. It is tempting to evoke increased anthropogenic disturbance as a causative factor explaining the decrease in lizard abundance on interior plots; however, the area disturbed on interior plots was very small and unlikely to negatively impact lizard numbers to any significant degree. In any case, each plot will be compared to itself and not to other plots. Therefore, initial differences in lizard abundance should not be a significant confounding factor in pre- and post-development analyses.

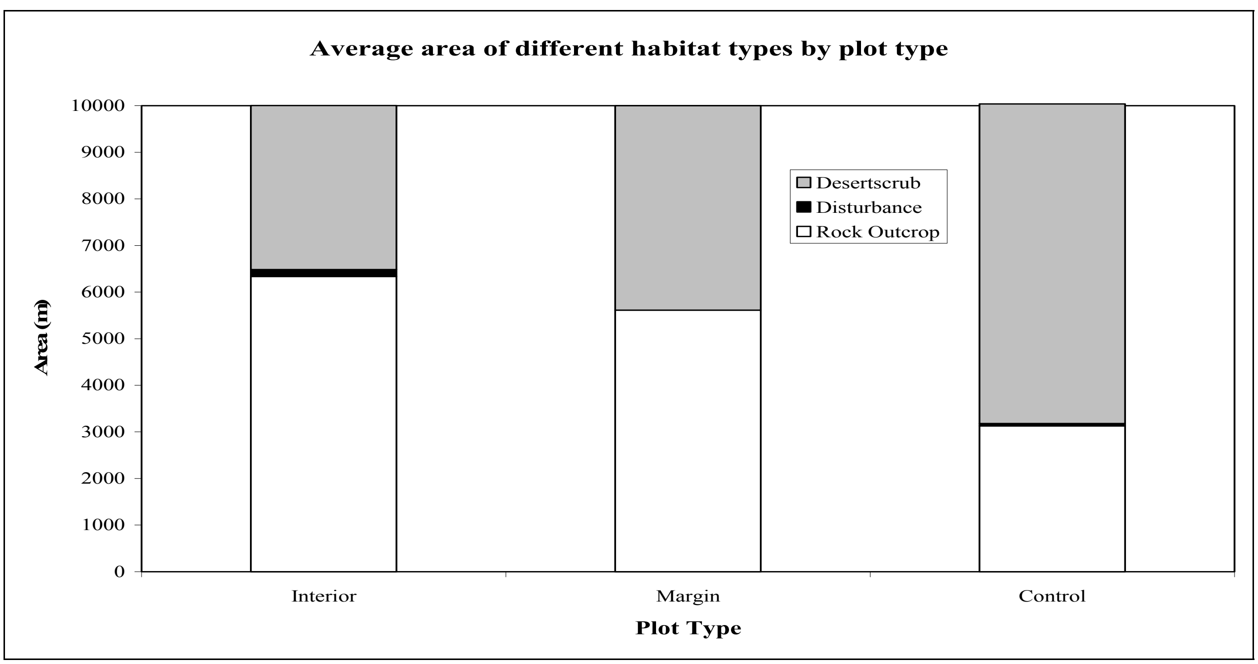


Figure 39. Mean area of all 16 plots within plot types (i.e., interior, margin, control) at the Stone Canyon study site that were classified into three categories (i.e., rock outcrop, disturbed, or desertscrub.

Landscape Changes Due To Urban Development

Urban development can cause dramatic changes to the landscape. We compared orthophotoquads of varying ages to illustrate changes to the desert resulting from the Stone Canyon and surrounding developments at the Rancho Vistoso complex (Figure 40 a-d). When viewed from above, changes to

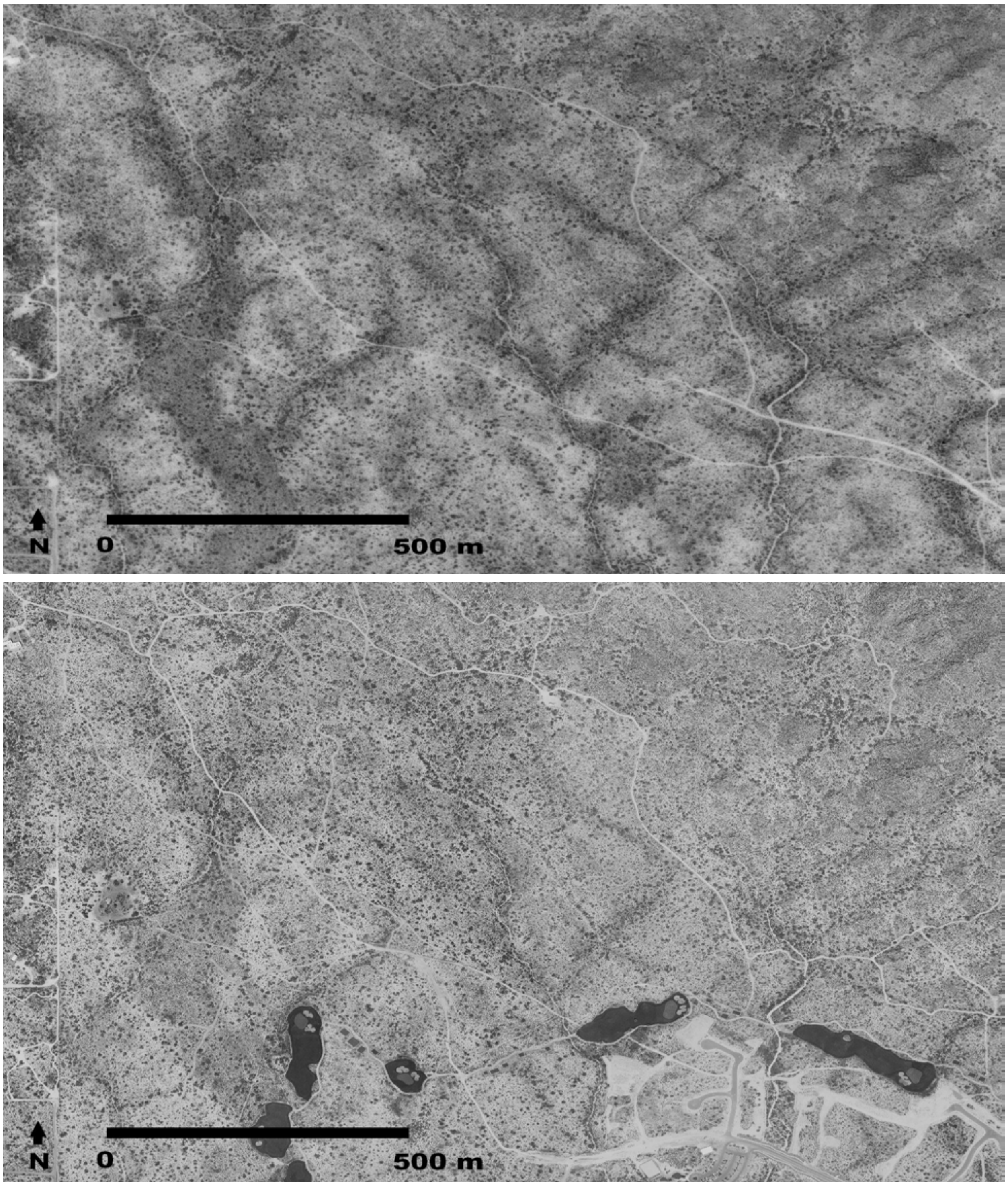


Figure 40 a, b. A series of four orthophotoquads (see next page for photos c and d) of the Stone Canyon development site near Oro Valley, Arizona. The top photograph was taken in 1992 and the bottom photograph was taken in 1998.

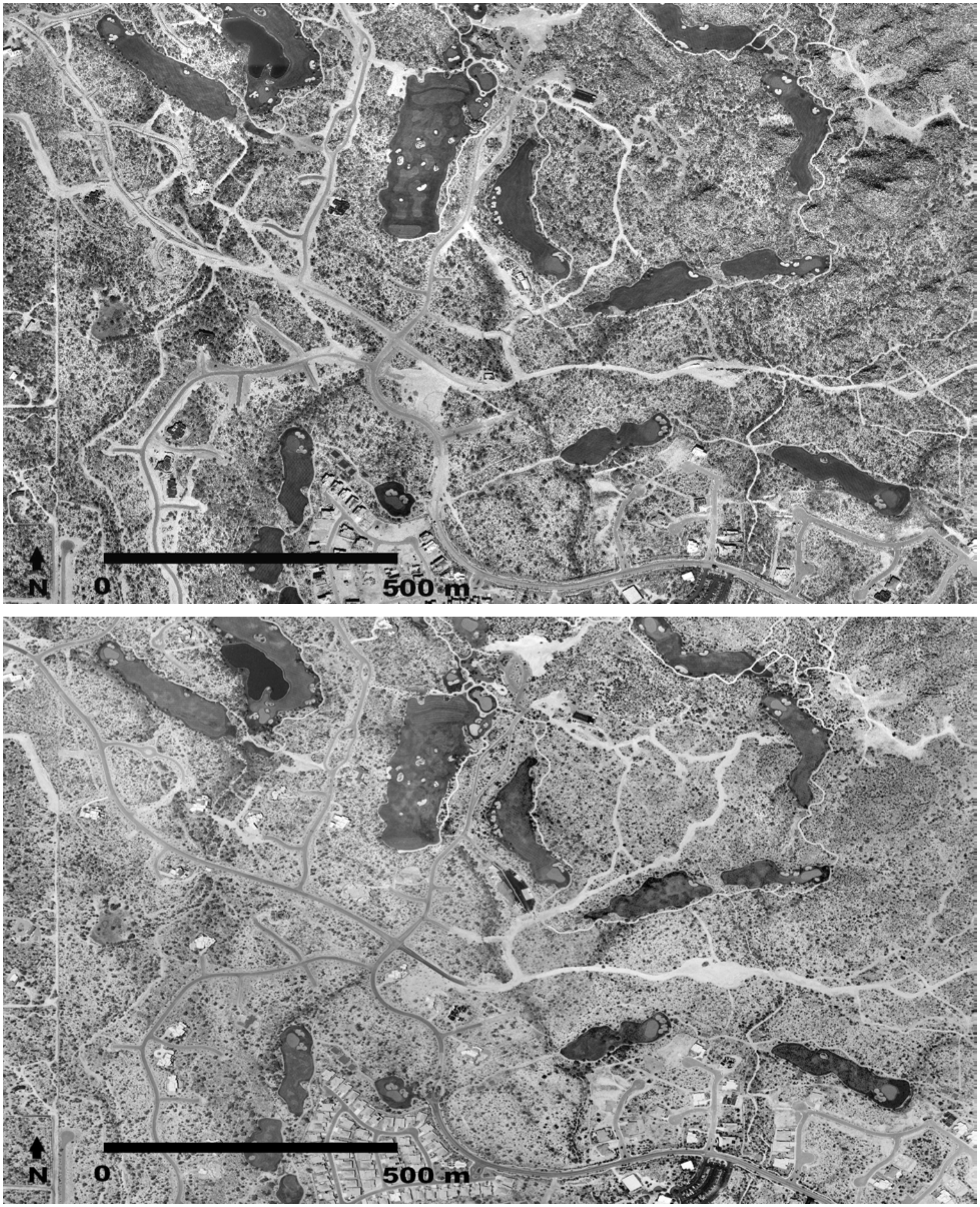


Figure 40 c,d. A series of four orthophotoquads (see previous page for photos a and b) of the Stone Canyon development site near Oro Valley, Arizona. The top photograph (c) was taken in 2000 and the bottom photograph was taken in 2002. In (a) part of an older development to the west and dirt roads to the east are visible. In (b) part of the golf course of the development immediately south of Stone Canyon has been constructed, a few new roads are constructed, and area has been cleared to accommodate numerous homes. In (c) the southern part of the Stone Canyon golf course, as well as numerous roads and a few houses. In (d) many roads at Stone Canyon are paved and there are more houses visible.

the landscape that may not seem as obvious from ground level, tend to stand out more. In addition, the availability of high resolution digital imagery, allows for advanced GIS analyses that would not otherwise be possible. We can easily track changes brought on by development using quantitative computer based tools. Due to high resolution imagery, and the small scale at which we are working, we will only need to spend a relatively short amount of time on ground truthing. As we continue to gather data at the site, we will monitor changes to the landscape so that potential changes in the ecology of amphibians and reptiles can be correlated with concomitant changes to the surrounding landscape. Our analysis will take place at several spatial and temporal scales.

RESEARCH AND MANAGEMENT RECOMMENDATIONS

Throughout the report, we have alluded to future research and made several management recommendations, which we attempt to summarize in this section. We feel that there are many possibilities for future research, because we have obtained a large pre-development dataset pertaining to several single-species, population, and community level parameters. The most obvious future research involves repeating the variety of surveys that we conducted as the development proceeds, and after it is completed. However, we mention several new research ideas stemming from the present study. Management recommendations are limited at present, because we have yet to gather post-development data. However, in a few cases, we obtained results that we feel have important management implications, and these are listed below.

Research Recommendations

1. Repeat TACS surveys

We suggest that TACS be repeated on all plots at a minimum of every five years for a minimum of 20-25 years. This is an ambitious recommendation, but this is the kind of timeframe that will be necessary to develop a realistic picture of potential effects of the development on amphibian and reptile community structure and composition. Ideally, surveys would be repeated for several decades, but it is difficult and even impractical to think of longer timeframes largely because the lifespan of a researcher's active career is only 30-40 years.

2. Repeat mark-recapture efforts

As with TACS, we suggest that mark-recapture efforts be repeated as long into the future as possible. It may be necessary to repeat mark-recapture of relatively short-lived lizards at smaller time intervals in order to obtain meaningful results, because natural fluctuations in population size are common. In any case, repeating mark-recapture efforts will require additional development of analytical techniques that can more effectively deal with the large amount of variation that is inherent in population size estimates. Analyzing population size trends rather than absolute values seems like a potentially informative approach.

3. Continue road cruising efforts

Road cruising and cart path surveys may be the most important activities to continue as the development proceeds, especially for nocturnally active animals such as most snake species, Gila monsters, and toads. The roads are public, providing access to the development that can be difficult if not impossible to obtain, because private property owners are unlikely to allow researchers onto their land. In addition, monitoring road mortality is critical, because it is one of the few ways to actually quantify direct effects of increased presence of humans, outside of very time intensive and costly autecological research that only yields information on a single species.

5. Continue golf path surveys

Perhaps the most unique aspect of this study was the opportunity to conduct golf path surveys. We suggest that golf path surveys be repeated as often as possible for as long as possible. Golf path surveys are inexpensive and do not require unreasonable amounts of time. They are also enjoyable, so getting people to continue to do them should not prove difficult. Golf path surveys yield data on relative abundance, community composition, and population structure. The golf path is essentially a permanent transect that has been conveniently placed in the middle of the development, and as such provides an excellent opportunity to develop a long-term dataset on herpetofauna that can be correlated with changes in development.

4. Continue radiotelemetry on tiger rattlesnakes

Our data on tiger rattlesnakes provides us with extremely detailed information about the ecology of an interesting species that is of some management concern. However, learning about the secret lives of tiger rattlesnakes will tell us very little about how development may affect the herpetofaunal community. On the other hand, detailed single-species research may provide information about potential causes of observed changes. For example, a trend of decreased relative abundance of rattlesnakes may be observed over time, as more and more snakes are run over by cars or killed by golfers and maintenance workers; however, the cause of decline would be difficult to detect without data on the fates of individuals that were obtained using radiotelemetry. In short, most of the data we have gathered during surveys only allows for correlations to be made, and as such, may be limited from a management perspective.

5. Increase efforts to document effects of development on toads

We uncovered some interesting patterns related to temporal and spatial differences in toad distributions and activity. We suggest that a more detailed research program focusing on the effects of the development be implemented, especially given the large amounts of water and the increase in potential breeding sites brought on by the golf course. However, due to the extreme variation in breeding cycles of explosively breeding anurans such as the toads present at the site that are dependent on unpredictable precipitation events, meaningful data on toad reproduction may be difficult to obtain. Researchers are busy developing more reliable and repeatable methods for monitoring toad populations in the desert Southwest (C. Schwalbe, personal communication), which may prove useful in the present context as well.

6. Continue to monitor focal species

We collected data on several more common species, some of which have special status, (e.g., Gila monsters, desert tortoises) in order to examine potential effects of development on a variety of population- and individual-level parameters. We recommend that this effort be continued in the future. Monitoring potential effects of development on parameters such as body size, population structure, sex ratios, reproduction and behavior patterns may be more informative than traditional parameters such as population size for which reliable estimates can be difficult to obtain.

7. Continue to monitor landscape changes

It is important to monitor changes to the landscape, because these changes will likely be correlated with any changes in herpetofauna. We think it is possible to quantify landscape changes at an appropriate scale using high resolution aerial photographs that can be manipulated in a GIS. Of course, this approach will depend on the availability of such imagery in the future, which seems likely based on past efforts by Pima County to maintain and make available to the public up-to-date, high resolution imagery.

8. Continue to monitor temperature and precipitation at the site

Continuing to keep good records on temperature and rainfall throughout the year is critical, because it will provide information that can help explain natural variation in the system. We are looking into the possibility of installing a permanent, automated weather station at the site.

9. Examine underlying mechanisms

Most of the data we have gathered will only allow for correlations to be made. We suggest that research designed to examine underlying mechanisms leading to potential changes be conducted. For example, we may detect a trend of decreasing abundance in a particular species, but without more detailed research, we will not be able to determine the proximate cause of the decrease. Perhaps it is the loss of suitable habitat, or a change in temperature that changes the animal's "physiological space". In any case, research designed to determine the actual causes leading to change will eventually be critical if we are to effectively mitigate negative impacts resulting from development.

10. Examine water quality issues

One potential future research project involves water quality issues. Because Stone Canyon is centered on a golf course, there is an enormous influx of water to the area. The course is watered frequently, and vegetation surrounding the course and homes is irrigated. In addition, there are several water impoundments associated with the golf course. Fertilizer and other chemicals are delivered via the irrigation and sprinkler systems, and algaecide and other chemicals are used to treat the water, which originates from ground water pumped by the town of Oro Valley. Research designed to examine the quality of this water and its potential effects on herpetofauna, especially aquatic species, would be of great interest and may lead to management recommendations.

11. Experimental habitat manipulations

We suggest that research be undertaken to examine the direct effects of habitat manipulation on herpetofauna. We have already approached the developer to provide us with a bulldozer or front-end loader to do the work necessary to prepare several building pads for home construction. We would conduct pre-construction surveys on numerous building pads associated with future home sites, manipulate the habitat, and then conduct post-construction surveys. This approach would essentially be a replicated experiment completed on a timeframe that would enable the results to be applied in a timely fashion, rather than waiting several years or even decades to obtain useable results. There are hundreds of future home sites at Stone Canyon that could be manipulated in a variety of ways, so small sample sizes would not be an issue as it so often is when studying the effects of large scale impacts such as developments.

12. Conduct similar research at other sites

It is important to conduct similar research at multiple sites in order to assess the amount of variation inherent to the system. If similar developments situated in similar areas were studied, then we would have a true before-after-control-impact study design. As it now stands, we have no way of determining if the results we obtain from the Stone Canyon site are truly representative. In this vein, Rancho Vistoso, the development company that is building Stone Canyon, will begin construction on another golf course development nearby and they have invited us to examine its effects on herpetofauna.

Management Recommendations

1. Build underpasses on main road encircling the golf course

Despite the fact that we have yet to obtain post-development data, one obvious management recommendation that we can already make is to install some kind of underpass or other structure that would allow amphibians and reptiles to safely cross the main road. Our data indicate that most tiger rattlesnakes spend the winter on the steep, rocky slopes above the golf course and then move down onto the golf course and its surroundings during the summer. The main road serving the development passes between these rocky slopes and the golf course. If snakes were able to safely pass under the road, it should significantly reduce road mortality. Designing roads that are more permeable to wildlife is becoming more common and is a good example of how a significant threat, road mortality, can be effectively mitigated without seriously compromising quality of life or economic benefits.

2. Continue and enhance educational efforts

We recently received AGFD funding to examine the effects of golf courses on herpetofauna. One of the courses we are studying is the Stone Canyon course. We also included an educational component to the project that involves placing interpretive signs along the golf course that will hopefully encourage golfers to become more acquainted with the wildlife with which they share the area. Another aspect of this project involves conducting a workshop for golf course managers and designers that we hope will lead to more wildlife-friendly golf courses. It is our belief that development will continue, so we need to do what we can to insure that these developments and their inhabitants will better coexist with wildlife. We feel that education is the most effective, sustainable way to positively effect conservation.

3. Get the community involved

If we fail to get the community involved in stewardship of their surroundings, then the impacts of development will be greater. Education is part of this, but we are exploring ways to get more direct involvement from the community. We will be addressing the Stone Canyon neighborhood association and golfers to inform them about our research. We are hoping to get residents involved in the actual research by reporting herpetofauna observations, especially when they observe marked individuals such as rattlesnakes with painted rattles or tortoises with notched scutes. In addition, we are planning on recruiting a few individuals to help with fund raising and to act as liaisons to other neighborhood associations in the area. In the end, we hope to get the community involved in as many ways as possible, with the ultimate goal being a sense of pride in the natural environment in which they are so fortunate to live. There are many wealthy and influential residents at Stone Canyon who could have a positive impact on conservation. Our goal is to tap into this untapped human resource.

ACKNOWLEDGMENTS

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APPENDIX A

Raw data from 63 western diamond-backed rattlesnakes, 43 black-tailed rattlesnakes, 84 tiger rattlesnakes, 47 collared lizards, 124 desert tortoises, 37 Gila monsters, and 48 regal horned lizards captured at Stone Canyon in 2002 and 2003, A = adult, J = juvenile, N = neonate, Repro = reproductive status, NG = not gravid, G = gravid, NS = no semen present, S = semen present, SVL = snout-vent length, MCL = mid-line carapace length, TL = tail length, HW = head width, HL = head length, RS = number of rattle segments, RL = rattle length, RB = rattle broken, Y = yes, and N = no. All measurements are in millimeters except mass, which is in grams.

Western Diamond-backed Rattlesnakes

Date	Age Class	Sex	Repro	SVL	TL	Mass
07/18/02	A	F	G	787	46	432
07/20/02	A	M		945	90	1057
07/20/02	A	M		1033	87	811
08/02/02	A	F	NG	804	46	451
08/02/02	N	M		322	19	22
08/09/02	N	F		327	19	25
08/09/02	N	M		308	27	44
08/09/02	N	M		369	29	41
08/09/02	A	M		1001	94	731
08/24/02	A	F	NG	774	50	306
08/25/02	N	F		357	23	30
08/25/02	N	M		346	27	29
08/28/02	A	F		869	58	373
08/28/02	N	M		331	26	32
08/29/02	N	M		365	32	32
08/29/02	A	M		830	59	401
08/30/02	A	M		811	65	362
09/01/02	N	F		323	22	29
09/01/02	A	M		880	88	750
09/04/02	A	F		758	49	288
09/05/02	N	F		319	20	27
09/22/02	N	F		365	25	37
10/09/02	A	M		762	64	341
10/11/02	A	M		869	81	493
07/06/03	A	M		894	82	585
07/11/03	A	M		853	62	338
07/18/03	A	F	G	899	50	592
07/28/03	A	F	G	1028	53	1018
07/30/03	A	F	G	913	51	580

Date	Age Class	Sex	Repro	SVL	TL	Mass
08/07/03	A	F	NG	847	57	407
08/14/03	N	M		345	26	29
08/15/03	A	M		1015	81	710
08/15/03	A			231	28	23
08/18/03	N	M		366	28	31
08/18/03	A	M		1128	91	1072
08/19/03	N	F		305	19	27
08/19/03	N	F		308	15	24
08/19/03	N	F		309	18	25
08/19/03	N	F		309	11	21
08/19/03	N	F		316	19	25
08/19/03	N	F		318	21	24
08/19/03	N	F		328	19	26
08/19/03	N	M		318	24	27
08/19/03	N	M		319	25	25
08/19/03	N	M		321	25	26
08/19/03	N	M		323	25	24
08/19/03	N	M		323	24	26
08/19/03	N	M		324	25	25
08/19/03	N	M		355	27	32
08/21/03	N	M		341	18	22
08/25/03	N	M		320	23	21
08/30/03	A	M		865	71	476
08/30/03	A	M		986	80	539
09/04/03	N	F		351	22	22
09/04/03	A	M	NS	1136	94	1370
09/06/03	N	F		370	21	29
09/07/03	N	M		336	25	31
09/11/03	A	M		842	74	479
09/11/03	A	M		1038	86	715
09/13/03	A			383	25	44
09/15/03	N	F		376	24	42
09/29/03	N	F		369	26	54
09/29/03	N	F		409	25	42

Black-Tailed Rattlesnakes

Date	Age Class	Sex	Repro	SVL	TL	Mass
07/11/02	A	F	NG	849	41	287
07/12/02	A	F	G	773	47	270
08/08/02	A	F	NG	924	61	393
08/09/02	A	M	S	924	77	284
08/21/02	A	F	NG	749	54	327
08/31/02	A	F		702	41	200
08/31/02	A	F		903	52	367
09/01/02	A	F		860	51	408
09/05/02	A	M		595	36	129
09/08/02	A	M		829	74	500
09/12/02	A	F		730	49	252
09/12/02	A	M		791	75	287
10/11/02	A	F	NG	985	59	798
10/24/02	A	F	NG	860	60	558
05/29/03	A	M		735	58	220
06/02/03	A	M		696	52	205
06/09/03	A	M		871	61	376
06/23/03	J	F		469	27	64
07/02/03	A	F	G	769	46	275
07/05/03	A	M		584	46	102
07/14/03	A	M		954	72	493
07/15/03	A	M		853	68	568
07/20/03	A	F		843	53	383
07/22/03	A	F	G	764	43	288
07/22/03	A	F	G	872	58	481
07/22/03	A	M	NS	1025	84	868
07/24/03	A	M	NS	847	62	402
07/27/03	A	F	NG	901	55	504
08/07/03	A	M		920	63	519
08/12/03	A	M		946	72	507
08/13/03	A	F	NG	781	36	123
08/19/03	N	M		353	28	32
08/19/03	N	F		354	22	30
08/19/03	A	F	NG	911	56	334
08/21/03	A	M	NS	898	68	407
08/21/03	A	M	NS	956	81	575
08/22/03	A	M	NS	893	69	420
09/07/03	A	M		840	71	301
09/08/03	A	M	S	886	79	633
09/14/03	A	M	S	966	78	530

Date	Age Class	Sex	Repro	SVL	TL	Mass
09/14/03	A	M	S	979	80	667
09/29/03	A	M		827	76	670
09/30/03	A	M		801	63	284

Tiger Rattlesnakes

Date	Sex	Age	Repro	SVL	TL	Mass	HW	HL	RS	RL	RB
07/12/02	F	A	NG	603	42	140	16	24	7	32	N
07/12/02	M	A		594	52	125	18	25	7	34	N
07/12/02	F	A	NG	652	44	170	19	29	7	27	Y
07/13/02	M	A		674	66	237	19	29	9	44	Y
07/15/02	M	A	NS	703	64	212	21	31	12	51	Y
07/17/02	M	A	NS	644	55	222	20	28	8	37	N
07/24/02	M	A	NS	590	56	173	19	27	7	32	N
07/23/02	M	A	NS	563	54	127	18	26	6	30	N
08/02/02	M	A	S	523	53	113	16	25	6	29	N
08/02/02	M	A	S	706	69	304	22	30	9	43	Y
08/07/02	M	A	S	641	60	287			8	33	Y
08/08/02	F	A		621	42	157	17	25	10	43	Y
08/08/02	M	A	S	723	71	351	23	30	8	32	Y
08/09/02	M	A	S	657	66	293	21	30	12	56	Y
08/09/02	M	A	NS	680	65	311	21	29	10	46	Y
08/09/02	M	A	S	548	52	138	18	26	6	28	N
08/11/02	M	A	S	540	44	115	20	24	7	32	N
08/26/02	F	A	NG	611	43	193	19	27	9	35	Y
08/30/02	F	A	NG	666	47	273	21	31	5	22	Y
08/31/02	M	A	S	628	62	293	21	28	8	37	Y
09/04/02	F	A	NG	666	40	192	20	27	10	46	Y
09/04/02	M	A	S	606	52	119	17	24	7	34	Y
09/04/02	F	A	G	573	44	235	19	26	3	15	Y
09/09/02	M	A	NS	648	62	282	21	27	8	39	N
09/12/02	M	A	NS	628	63	275	23	27	7	34	Y
09/13/02	M	A	S	552	52	136	17	24	6	30	N
09/15/02	M	A		711	69	285	33	28	10	47	Y
09/16/02	M	A	S	651	66	345	20	27	11	47	Y
09/16/02	F	A	G	622	41	278	19	25	10	40	N
09/16/02	F	A	NG	531	40	142	20	26	7	28	Y
09/27/02	M	A		616	54	185	23	29	8	42	Y
09/22/02	M	N		316	26	23	15	18	1	9	N
09/28/02	F	A	NG	664	48	271	20	29	7	27	Y
10/09/02	F	A		570	42	186					Y

Date	Sex	Age	Repro	SVL	TL	Mass	HW	HL	RS	RL	RB
10/11/02	M	A		643	59	256	23	28	7	34	N
06/08/03	M	A		667	63	272	20	28	11	48	Y
06/09/03	F	A	NG	541	43	126	17	25	6	33	N
06/21/03	M	A	S	683	70	340	20	28	8	42	Y
06/29/03	M	A	S	621	62	206	20	27	8	37	N
07/01/03	F	A	G	576	40	208	16	24	7	29	Y
07/06/03	F	J		418	28	50	15	22	3		N
07/06/03	M	A	S	601	56	173	21	27	7	33	Y
07/08/03	M	A		571	54	118	18	27	8	38	N
07/13/03	M	A	NS	563	60	170	18	26	7	33	N
07/15/03	F	A		610	45	185	19	24	10	41	N
07/18/03	F	A	NG	597	39	176	20	27	9		N
07/18/03	M	A	S	620	63	167	19	27	5	25	Y
07/21/03	M	A	S	649	62	331	22	26	8	39	Y
07/22/03	F	N		261	19	13	12	18	1	9	N
07/22/03	F	N		255	19	13	12	17	1	8	N
07/22/03	F	J		425	29	59	16	22	3	21	N
07/23/03	F	N		259	16	14	12	18	1	9	N
07/23/03	M	A	NS	532	50	129	18	26	4	23	Y
07/23/03	M	A	S	661	65	306	21	28	8	37	Y
07/23/03	M	A	S	682	64	325	21	28	9	44	Y
07/24/03	M	A	S	532	49	110	19	26	7		N
07/27/03	M	A		659	73	292	21	28	11	54	Y
07/28/03	M	A	NS	688	59	278	21	28	6	30	Y
07/30/03	M	A	NS	686	65	292	21	29	3	18	Y
07/30/03	F	A	NG	628	43	229	20	28	9	44	Y
07/31/03	M	A	S	763	78	419	24	32	11	58	Y
08/02/03	F	A	NG	555	40	126	18	24	6	26	Y
08/07/03	M	A	NS	715	58	302	22	29	8	37	
08/07/03	M	A	S	642	56	233	20	28	8	38	N
08/09/03	F	A	NG	623	42		20	27	9	41	Y
08/11/03	M	A	NS	710	70	395	43	50	10	43	Y
08/14/03	M	A	NS	597	57	192	18	26	8	36	N
08/18/03	M	A	NS	628	62	244	21	28	10	45	Y
08/18/03	M	A		676	64	306	19	30	7	38	Y
08/20/03	M	A	S	655	64	284	21	31	7	33	Y
08/21/03	M	J	NS	376	33	45	15	31	2	14	N
08/22/03	M	A	NS	684	65	315	22	29	10	43	Y
08/22/03	M	A	S	672	62	263	21	29	8	39	Y
08/23/03	F	A	NG	544	44	143	19	25	7	33	N
08/30/03	M	A	S	619	172	240	20	27	5	26	Y
09/03/03	F	A	NG	522	37	125	18	25	5	26	N

Date	Sex	Age	Repro	SVL	TL	Mass	HW	HL	RS	RL	RB
09/03/03	M	A		592	55	198	20	27	6	30	Y
09/04/03	M	A	NS	555	56	148	18	25	7	34	N
09/04/03	F	A	NG	528	39	118	18	24	5	24	N
09/08/03	F	A	G	587	50	203	19	27	9	38	Y
09/09/03	F	A	NG	605	41	249	19	26	10	39	Y
09/11/03	F	A	G	587	42	228	19	26	8	35	N
09/15/03	F	A	NG	668	48	215	21	26	4	20	Y

Collared Lizards

Date	Age Class	Sex	SVL	TL	Mass	HW	HD
06/06/02	A	F	76.2	163.0	12.0	17.3	21.6
07/09/02	A	F	79.9	164.0	18.0	18.9	25.9
07/24/02	A	F	81.9	177.0	21.5	20.0	24.0
07/03/02	A	F	82.4	162.8	19.5	19.4	25.8
06/07/02	A	F	82.8	178.0	22.5	18.2	23.3
07/26/02	A	F	84.7	177.4	21.8	20.7	25.4
07/11/02	A	F	84.8	184.0	33.5	20.3	25.7
07/14/03	A	F	85.0	180.0	22.0	19.3	26.7
05/30/02	A	F	86.0	196.0	27.5	24.0	
05/31/02	A	F	86.0	170.0	20.0	22.0	
05/20/03	A	F	86.0	194.0	26.0	22.0	28.5
08/26/02	A	F	87.2	188.0	28.5	28.1	26.5
07/04/02	A	F	87.5	167.3	27.0	17.8	24.4
05/31/02	A	F	88.0	173.0	25.5	22.0	
08/18/03	A	F	88.0	186.0	22.0		25.8
08/17/03	A	F	88.0	188.0	23.0	21.1	24.5
06/24/02	A	F	90.2	193.5	33.0	21.2	24.8
06/19/02	A	F	90.2	184.0	26.5	19.4	25.9
07/14/02	A	F	90.2	189.0	19.4	20.3	24.9
07/10/02	A	F	91.2	175.4	25.3	21.5	27.0
08/03/02	A	F	91.4	199.0	36.5	22.0	25.1
05/31/02	A	F	92.0	119.0	24.5	23.0	
07/01/03	A	F	95.0	194.0	22.0	21.3	27.0
09/23/02	J	M	48.2	96.9	5.0	12.9	15.8
05/30/02	J	M	74.0	167.0	15.5	19.0	
07/07/02	A	M	85.0	209.0	25.5	19.8	26.1
05/30/02	A	M	87.0	197.0	24.0	21.0	
06/11/02	A	M	88.5	200.0	28.0	20.6	25.3

Date	Age Class	Sex	SVL	TL	Mass	HW	HD
07/25/02	A	M	88.7	174.0	28.0	22.9	27.6
06/06/02	A	M	89.3	185.0	24.0	21.6	26.6
05/31/02	A	M	90.0	187.0	29.0	23.0	
06/14/02	A	M	94.4	197.0	34.5	22.3	26.3
07/09/02	A	M	95.5	196.7	28.2	23.9	30.6
05/30/02	A	M	97.0	222.0	49.0	29.0	
07/11/02	A	M	97.0	221.0		25.8	31.5
05/30/02	A	M	99.0	217.0	43.0	29.0	
07/29/02	A	M	100.0	226.0	41.0	23.0	31.0
07/24/02	A	M	101.4	223.4	41.0	25.6	33.3
07/24/02	A	M	101.4	206.0	40.0	26.4	30.5
07/21/02	A	M	101.6	211.8	42.0	25.9	30.7
07/04/02	A	M	102.7	207.1	32.5	26.0	31.7
07/07/02	A	M	104.6	199.0	35.0	25.9	34.5
08/18/03	J	U	38.5	69.0	2.2	10.6	12.5
09/12/03	J	U	40.0	70.0	2.4	10.8	12.9
08/17/03	J	U	41.5	69.0	2.4	10.5	13.1
08/18/03	J	U	46.0	83.0	3.4	11.8	14.4
09/08/03	J	U	49.5	94.0	4.5	13.1	15.4

Desert Tortoises

Date	Age	Sex	MCL
05/31/02	A	M	200.0
07/08/02	A	M	255.0
07/10/02	A	M	201.0
07/15/02	A	M	214.0
07/21/02	J		137.0
07/21/02	A	F	216.0
07/23/02	A	F	215.0
07/25/02	J		78.0
07/28/02	J	F	162.0
07/28/02	J	F	175.0
07/28/02	A	M	232.0
07/28/02	A	M	233.0
07/28/02	A	M	236.0
07/28/02	A	F	255.0
07/28/02	A	F	258.0
07/29/02	A	M	246.0
07/29/02	A	M	285.0

Date	Age	Sex	MCL
07/30/02	J		138.0
07/30/02	A	M	230.0
08/02/02	A	F	213.0
08/08/02	A	F	228.0
08/10/02	J		122.0
08/10/02	A	M	280.0
08/12/02	A	F	223.0
08/12/02	A	M	229.0
08/12/02	A	M	298.0
08/14/02	J		74.0
08/20/02	A	F	261.0
08/21/02	A	M	264.0
08/22/02	J		162.0
08/26/02	A	M	265.0
08/28/02	J		105.0
08/28/02	A	M	209.0
08/29/02	A	F	221.0
09/02/02	J		106.0
09/02/02	A	M	235.0
09/04/02	A	M	241.0
09/05/02	A	M	247.0
09/09/02	A	M	276.0
09/10/02	J		164.0
09/10/02	A	M	255.0
09/10/02	A	M	271.0
09/11/02	A	M	260.0
09/13/02	A	M	209.0
09/19/02	A	M	262.0
10/13/02	A	F	239.0
10/20/02	A	M	237.0
02/19/03	A	M	302.0
07/01/03	J		102.0
07/01/03	J		102.0
07/01/03	A	M	211.0
07/01/03	A	M	239.0
07/07/03	A	M	184.0
07/10/03	J		102.0
07/14/03	J		155.0
07/14/03	A	F	237.0
07/15/03	J	M	145.0
07/16/03	A		181.0
07/16/03	A	M	250.0

Date	Age	Sex	MCL
07/21/03	J		70.0
07/21/03	A	M	223.0
07/23/03	J		51.0
07/23/03	A	F	256.0
07/24/03	J	F	172.0
07/24/03	A	M	219.5
07/24/03	A	M	229.5
07/26/03	J		69.0
07/26/03	J		76.2
07/26/03	J	F	162.5
07/29/03	A	M	207.0
07/31/03	A	F	232.0
07/31/03	A	M	251.0
08/01/03	J	F	121.0
08/01/03	A	M	243.0
08/03/03	J		81.0
08/03/03	A	M	202.4
08/04/03	J		78.0
08/04/03	J		129.0
08/06/03	J		124.5
08/06/03	J		134.0
08/07/03	A	F	254.0
08/07/03	A	M	274.0
08/11/03	A		204.0
08/11/03	A	M	300.5
08/13/03	A		280.0
08/14/03	A	M	212.0
08/14/03	A	F	227.0
08/14/03	A	F	230.0
08/14/03	A	F	255.0
08/15/03	A	M	194.0
08/15/03	A	F	227.0
08/15/03	A	M	235.0
08/16/03	A	F	227.0
08/18/03	J	F	167.0
08/18/03	A	F	229.0
08/19/03	J		103.0
08/19/03	A	F	253.0
08/19/03	A	M	262.5
08/19/03	A	F	263.0
08/19/03	A	M	263.0
08/20/03	A	M	192.5

Date	Age	Sex	MCL
08/20/03	A	F	249.0
08/21/03	A	M	224.0
08/21/03	A	M	234.0
08/21/03	A	M	243.0
08/21/03	A	F	246.0
08/21/03	A	F	252.0
08/22/03	A	F	228.0
08/24/03	A	M	228.0
08/26/03	A	M	205.0
09/05/03	A	M	215.0
09/06/03	A	M	213.0
09/06/03	A		213.0
09/07/03	J		107.0
09/07/03	J		158.0
09/07/03	A	M	220.0
09/07/03	A	M	222.0
09/08/03	A	M	255.5
09/10/03	A	M	268.0
09/12/03	A	M	225.0
09/13/03	A	F	214.0
09/13/03	A	M	282.0
09/14/03	J		95.2
09/19/03	A	M	235.0

Gila Monsters

Date	Age Class	SVL	TL	Mass	HW	HD
04/26/02	A	291	106	401	44.4	
05/31/02	A	306	119	409		
07/09/02	A	235	73	208	37.3	47.2
07/11/02	J	155	64	54	26.8	
07/17/02	A	221	70	143	32.6	41.3
07/23/02	A	318	103	421	46.3	55.1
08/31/02	A	251	77	287	39.5	49.5
09/09/02	A	417	143	394	47.4	61.2
09/22/02	A	309	106	459	45.4	57.6
09/25/02	A	267	119	280	39.9	50.1
09/25/02	A	328	136	505	48.6	61.5
10/07/02	A	332	141	591	46.0	60.0
03/23/03	A	304	118	413	46.2	54.1
04/27/03	J	183	90	79	28.4	37.7

Date	Age Class	SVL	TL	Mass	HW	HD
05/20/03	A		107	472	48.0	48.4
05/29/03	A	292	92	535	47.2	57.8
05/31/03	A	267	123	362	41.4	49.5
06/25/03	J	199	88	115	34.3	41.5
07/06/03	A	318	13	371	45.0	62.0
07/07/03	J	152	62	37	21.6	31.6
07/19/03	A	319	131	426	55.5	60.2
07/20/03	A	308	117	384	47.2	57.2
07/22/03	A	305	123	365	43.1	54.2
07/27/03	A	300	133	322	45.3	56.3
08/01/03	J	148	69	58	24.0	32.5
08/05/03	A	297	128	378	47.2	56.6
08/09/03	A	284	124	231	34.0	53.5
08/09/03	A	284	96	327	40.6	50.7
08/14/03	A	309	97	309	46.1	58.1
08/17/03	A	231	104	186	34.4	46.8
09/01/03	A	323	123	531	51.3	60.5
09/02/03	A	301	131	526	50.7	56.8
09/04/03	A	301	126	504	47.3	54.5
09/05/03	A	330	109	336	46.4	55.8
09/06/03	A	312	122	407	42.0	53.5
09/07/03	A	308	102	384	49.0	58.2
09/21/03	A	283	127	441	45.6	52.5

Regal Horned Lizards

Date	Age Class	Sex	SVL	TL	Mass	HW	HD
08/06/02	A	M	87.7	46.7	46.0	24.7	25.1
08/14/02	A	M	77.8	38.0	31.0		
08/22/02	A	M	77.0	37.0	27.0	24.0	
08/22/02	A	M	85.2	43.9	42.0	26.9	
08/24/02	A	F	83.1	29.0	28.5	24.5	
09/20/02	A	F	86.5	35.8	50.0		
09/22/02	J		36.6	12.7	2.7	11.6	
09/22/02	A	F	94.3	35.8	47.0	26.2	
09/30/02	A	F	96.3	38.4	63.0	28.8	
10/24/02	J	M	41.7	12.5	4.7	13.3	
05/13/03	J	F	51.6		9.2		
05/18/03	A	F	105.0	39.0	77.0	28.3	
05/26/03	A	F	88.0	36.0	50.5	27.5	
05/27/03	A	M	87.0	42.0	32.0	27.0	23.9

Date	Age Class	Sex	SVL	TL	Mass	HW	HD
06/05/03	A	M	92.0	46.0	55.0	27.9	25.3
06/09/03	A	F	101.0	37.0	60.0	27.9	24.0
06/16/03	J	F	61.2	23.5	13.0	20.0	17.8
06/16/03	A	M	94.0	53.0	61.0	29.3	25.7
06/25/03	A	M	97.0	50.0	51.0		
06/26/03	A	M	95.0	58.0	55.0	28.4	25.0
06/30/03	J		55.0	21.0	11.0	18.2	17.2
06/30/03	A	M	90.0	49.0	32.0	28.2	24.0
07/01/03	A	F	140.0	37.0	72.0	29.3	25.9
07/01/03	A	F	140.0	37.0	72.0	29.3	25.9
07/03/03	A	M	84.0	42.0	30.5	22.0	20.3
07/04/03	A	M	78.0	45.0	24.0	22.5	20.4
07/07/03	A	M	91.0	47.0	41.0	28.0	24.0
07/08/03	J	M	62.0	28.0	10.5	19.2	
07/11/03	A	M	82.0	45.0	34.0	25.6	22.5
07/12/03	A	F	101.0	37.5	74.5	27.3	24.6
07/19/03	A	M	86.5	46.0	36.0	25.5	22.0
07/19/03	A	M	89.0	39.0	38.0	24.7	21.6
07/19/03	A	F	105.5	33.5	77.0	28.0	26.1
07/22/03	A	M	84.5	51.0	36.5	25.2	22.0
07/22/03	A	F	107.5	39.0	66.0	28.0	25.5
07/23/03	J	M	68.5	29.5	16.0	21.8	19.4
07/23/03	A	M	73.5	41.0	21.5	21.0	29.0
07/24/03	A	F	94.5	39.8	55.2	27.2	23.4
07/25/03	A	F	98.5	39.0	45.5	27.6	24.8
07/25/03	A	F	110.0	44.5	86.5	30.3	27.9
07/28/03	A	F	113.0	38.5	72.5	28.9	25.7
07/29/03	A	F	102.0	41.0	58.0	25.2	28.0
07/30/03	A	M	98.0	54.0	79.0		
07/31/03	A	F	102.7	36.2	52.0	27.5	26.3
08/01/03	A	F	103.0	40.0	43.0	28.0	24.2
08/07/03	A	M	89.9	47.5	44.5	28.2	24.5
08/16/03	A	F	89.5	31.0	32.3	24.0	21.4
09/13/03	J	M	32.2	12.5	1.9	10.5	9.5